NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

THESIS

INVESTIGATION OF SECOND GENERATION CONTROLLED-DIFFUSION COMPRESSOR BLADES IN CASCADE

by

Dennis J. Hansen

September, 1995

Thesis Advisor: Garth V. Hobson

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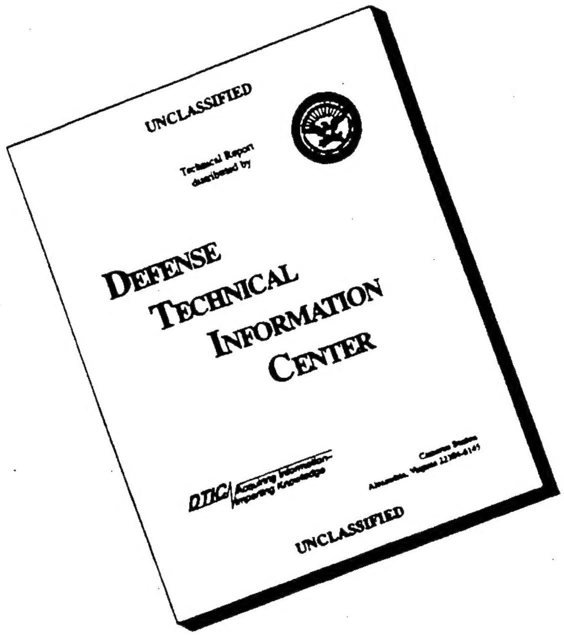

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13. ABSTRACT *(maximum 200 words)*

Detailed experimental investigation of second generation controlled-diffusion compressor stator blades at design inlet-flow angle was performed in a low-speed cascade wind tunnel using various experimental methods. Surface pressure measurements were obtained using three instrumented blades, from which coefficients of pressure were calculated. Laser-Doppler velocimetry was used to characterize the flow in the inlet, in the passage between two blades, in the boundary layer of the blades, and in the wake. A five-hole pressure probe was used to determine the loss coefficient and the axial-velocity-density ratio of the flow through the cascade. Although the blades produced significant lift, separated flow was discovered on the suction side of the blades at approximately fifty percent axial chord, which showed that the design was not totally successful. All the experimental measurements were performed at an inlet flow Mach number of 0.22 and a Reynolds number, based on chord length, of 640,000.

Experimental blade-surface pressure coefficients were compared with values predicted using a computational fluid dynamics code. These initial predictions did not match well with the experimental results.

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INVESTIGATION OF SECOND GENERATION CONTROLLED-DIFFUSION COMPRESSOR BLADES IN CASCADE

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LIST OF SYMBOLS

c	blade chord
$c_{uv} = \dfrac{\overline{u'v'}}{\sqrt{\overline{u'}^2}\sqrt{\overline{v'}^2}}$	correlation coefficient
C_{ij}	polynomial coefficients for dimensionless velocity
c_{ac}	blade axial chord
Cp	coefficient of pressure
C_{ps}	coefficient of static pressure
C_{psus}	coefficient of static pressure, upstream location
C_{pt}	coefficient of total pressure
C_{ptds}	coefficient of total pressure, upstream location
C_{ptus}	coefficient of total pressure, downstream location
d	distance from the blade surface
K_{ds}	five-hole probe reference flow function, downstream location
K_{us}	five-hole probe reference flow function, upstream location
M	Mach number
P_1	five-hole probe total pressure
P_2	five-hole probe yaw pressure
P_3	five-hole probe yaw pressure
P_{23}	five-hole probe average yaw pressure
P_4	five-hole probe pitch pressure
P_5	five-hole probe pitch pressure
P_s	Prandtl static pressure
P_t	Prandtl total pressure
Re_c	Reynolds number based on blade chord
S	blade pitch/spacing
T_t	plenum total temperature

$T_u = \dfrac{\sqrt{\overline{u'^2}}}{V_{ref}}$	axial turbulence intensity
$T_v = \dfrac{\sqrt{\overline{v'^2}}}{V_{ref}}$	tangential turbulence intensity
U	axial velocity component
u'	axial fluctuating velocity
$\overline{u'v'}$	Reynolds stress
V	tangential velocity component
V_{ref}	reference velocity
V_t	limiting five-hole probe velocity
v'	tangential fluctuating velocity
$W = U \cdot \vec{i} + V \cdot \vec{j}$	total velocity
x	axial direction
X	dimensionless velocity
X_{ref}	reference dimensionless velocity
y	tangential direction
β	dimensionless velocity coefficient
β_1	tunnel inlet flow angle
β_{1w}	tunnel sidewall setting angle
β_2	tunnel outlet angle
β_{2w}	tunnel tailboard setting angle
$\beta_{5\text{-hole}}$	five-hole yaw angle
γ	ratio of specific heats
$\gamma_{5\text{-hole}}$	five-hole probe pitch angle coefficient
$\delta = \dfrac{c}{S}$	blade solidity
η	axis normal to blade chord

ξ	axis tangent to blade chord
ω	loss coefficient

ACKNOWLEDGMENT

I would like to acknowledge the financial support of NAVAIR, which sponsored this work as part of the fan and compressor stall project.

I would like to thank Professor Garth Hobson for his enthusiasm, patience and wisdom that he displayed during the past year, making this an enjoyable learning experience. I am also grateful to Professor Raymond Shreeve for the advice and guidance which he generously gave to me. Thanks also to Mr. Rick Still and Mr. Ted Best, the NPS Turbopropulsion Lab technicians, for the continuous support, assistance and humor. A special thanks to Anna for her support, understanding and encouragement during the past year.

I. INTRODUCTION

A. BACKGROUND

Increased performance requirements for aircraft gas turbine engines necessitate continuous progress in gas turbine engine research and development. Engine compressor stall and off-design behavior continue to limit the performance of military aircraft gas turbine engines. Compressor stall can lead to degradation in engine performance or even total loss of engine power, which could result in mission failure or aircraft loss. Additionally, the increased thrust-to-weight ratio engines needed for present and future military and civil aircraft require improved compressor design for increased performance at the same or reduced weight.

Compressor blading has progressed over the years from the use of NACA-65 series, Double Circular Arc (DCA) and Multiple Circular Arc (MCA) bladeshapes to the design of Controlled-Diffusion (CD) blading. CD blading was developed to control diffusion on the suction side of the airfoil, thus avoiding boundary-layer separation at the engine design point. Transonic design allowed shock-free operation in the transonic range which increased compressor and engine efficiency. The resulting increase in efficiency could be used to improve engine performance, or the same engine performance could be achieved using fewer compressor blades, allowing a reduction in engine weight.

The CD compressor blades investigated in the present study were designed by Thomas F. Gelder of NASA Lewis Research Center (LeRC) [Ref. 1]. The compressor stator profiles were Stator 67B blades, which together with Rotor 67 comprised Compressor Stage 67B. Compressor Stage 67B was previously studied experimentally at the NASA LeRC compressor test facility [Ref. 1]. The Stator 67B blades were second generation CD blades which were designed as an improvement to the Stator 67A CD blades. The Stator 67A blades, designed by Nelson Sanger [Ref. 2] , coupled with Rotor 67 to form Stage 67A. Ten midspan Stator 67B blade profiles were machined from

aluminum and installed in the Naval Postgraduate School (NPS) Turbopropulsion Laboratory (TPL) Low-Speed Cascade Wind Tunnel (LSCWT) for the present study. Pneumatic probe measurements were made upstream and downstream of the blading. Laser-Doppler velocimetry (LDV) measurements were performed upstream of the blade row, in the passage between the blades, in the boundary layers, and downstream in the wake, at the design inlet-flow angle. A quasi-three dimensional computational fluid dynamics (CFD) code, Rotor Viscous Code Quasi-3-D (RVCQ3D) Version 300, was also used for comparison with the experimental results.

The Stator 67A compressor blading was the focus of a decade of research at the NPS TPL. Koyuncu [Ref. 3] studied the performance at various incidence angles using a five-hole probe. Dreon [Ref. 4] improved the accuracy in loss and pressure measurement near design conditions. Elazar [Ref. 5] performed LDV measurements in the boundary layer, in the blade passage and in the wake at three incidence angles. Murray [Ref. 6] upgraded the LDV system and measured the flow in the wake near stall. Classick [Ref. 7] upgraded the pressure probe data acquisition software and performed surveys near stall. Armstrong [Ref. 8] further improved the data acquisition system and compared flow at high incidence angles over a blade with a modified leading edge and an unmodified blade. Hobson and Shreeve [Ref. 9] used LDV to study the flow at very high incidence. Ganiam [Ref. 10] performed LDV measurements at stall. Williams [Ref. 11] verified the LDV measurements at stall and obtained a prediction using computational fluid dynamics (CFD).

B. PURPOSE

The objective of the present study was to install the Stator 67B midspan blade sections in the NPS cascade and to examine the flow through the blading at the design inlet-flow angle using LDV and pressure probe measurements. The intent was first to obtain a thorough understanding of the flow at the design inlet-flow angle, and to validate

the design itself. Future studies of Stator 67B cascade blading at higher inlet-flow angles will determine the off-design and stalling behavior.

II. TEST FACILITY AND INSTRUMENTATION

A. LOW-SPEED CASCADE WIND TUNNEL

The NPS Turbopropulsion Laboratory Low-Speed Cascade Wind Tunnel Building is shown in Figure 1. Elazar [Ref. 5] thoroughly documented the uniformity of tunnel flow conditions and the periodicity of the flow in the cascade test section with 20 Stator 67A blades in the cascade at 40 (design), 43 and 46 degrees inlet-flow angle.

B. TEST SECTION

A schematic of the cascade is shown in Figure 2. Ten CD blades with elliptical leading- and trailing-edges were scaled from the midspan section of Stator 67B [Ref. 1] and machined from aluminum using numerically-controlled machining methods. Figure 3 shows the profile of the blade. Table 1 contains the machine coordinates used to manufacture the blades. Three blades were instrumented with pressure taps which were machined into fine metal tubing laid into the blade surface. A fully-instrumented blade containing 42 pressure taps was installed at blade location number 6 [Figure 2]. Two blades numbered 2 and 8 were partially instrumented with eight pressure taps each. Figure 4 shows the pressure tap locations on the instrumented blades. Additionally, blades 3 and 4 were treated with a black anodized coating to minimize laser light scatter for the LDV measurements. The LDV test passage between blades 3 and 4 is shown in Figure 5 with the locations of the 13 measurement stations shown as fractions of the axial chord (C_{ac}). Table 2 contains a summary listing of the geometrical parameters of the cascade test section.

The ten blades were installed in the test section using brass shims for alignment perpendicular to the cascade endwalls. A digital inclinometer with an accuracy of 0.1 degrees was used to set the stagger angle of the blades. The tunnel inlet sidewalls were

adjusted to the design inlet-flow angle, $\beta_1 = 36.3$ degrees. The inlet guide vanes were adjusted until the mean inlet flow to the test section at Station 1 was equivalent to the design inlet-flow angle. The final tunnel adjustment was that of the tail board setting angles which were adjusted to give uniform wall static pressures downstream of the blading [Figure 2].

C. INSTRUMENTATION

1. Pneumatic Data Acquisition System

Two different pneumatic data acquisition systems were used with a traversing five-hole probe to determine the loss coefficient (ω), the axial-velocity-density ratio (AVDR), and blade surface pressure coefficients (Cp). The first system was a computer-controlled automated data acquisition system and software documented by Classick [Ref. 7] and modified by Armstrong [Ref. 8]. The Hewlett-Packard data acquisition system hardware and software “ACQUIRE” and “LOSS” are fully described by Armstrong [Ref. 8].

The second data acquisition system consisted of a Scanivalve Digital Interface Unit (SDIU Mk5), a Scanivalve Controller (CTLR2/S2-S6), a Hewlett-Packard digital voltmeter (HP 3437A) and a 48 channel Scanivalve rotary pressure scanner. Loss and AVDR calculations were performed using a personal computer with the spreadsheet software Microsoft “Excel”. The five-hole probe and the five-hole probe traverse used for both systems are shown in the photographs in Figures 6 and 7. Figure 8 shows a schematic of the second data acquisition system. Plenum pressure and temperature sensors were the same as those used in the first system. A Prandtl probe located upstream of the test section was used as the total pressure reference for the second system.

Prior to implementation of either of the two acquisition systems, a series of surface pressure measurements was performed using banks of water manometers. The partially-instrumented blades, mounted at blade position numbers 2 and 8 in the test section, were

connected to manometers for an initial observation of the pressure distribution over the blades.

2. Laser Doppler Velocimeter

A four beam, two color TSI Model 9100-7 LDV system was used for all surveys. Elazar [Ref. 5] thoroughly described the LDV system, including the laser model, optics, atomizer and seeding, and data acquisition. Murray [Ref. 6] described the fully automated traverse mechanism. The LDV and traverse systems were controlled by a personal computer. Experimental data were processed using TSI FIND software on the personal computer. The LDV and traverse systems are shown in Figure 9.

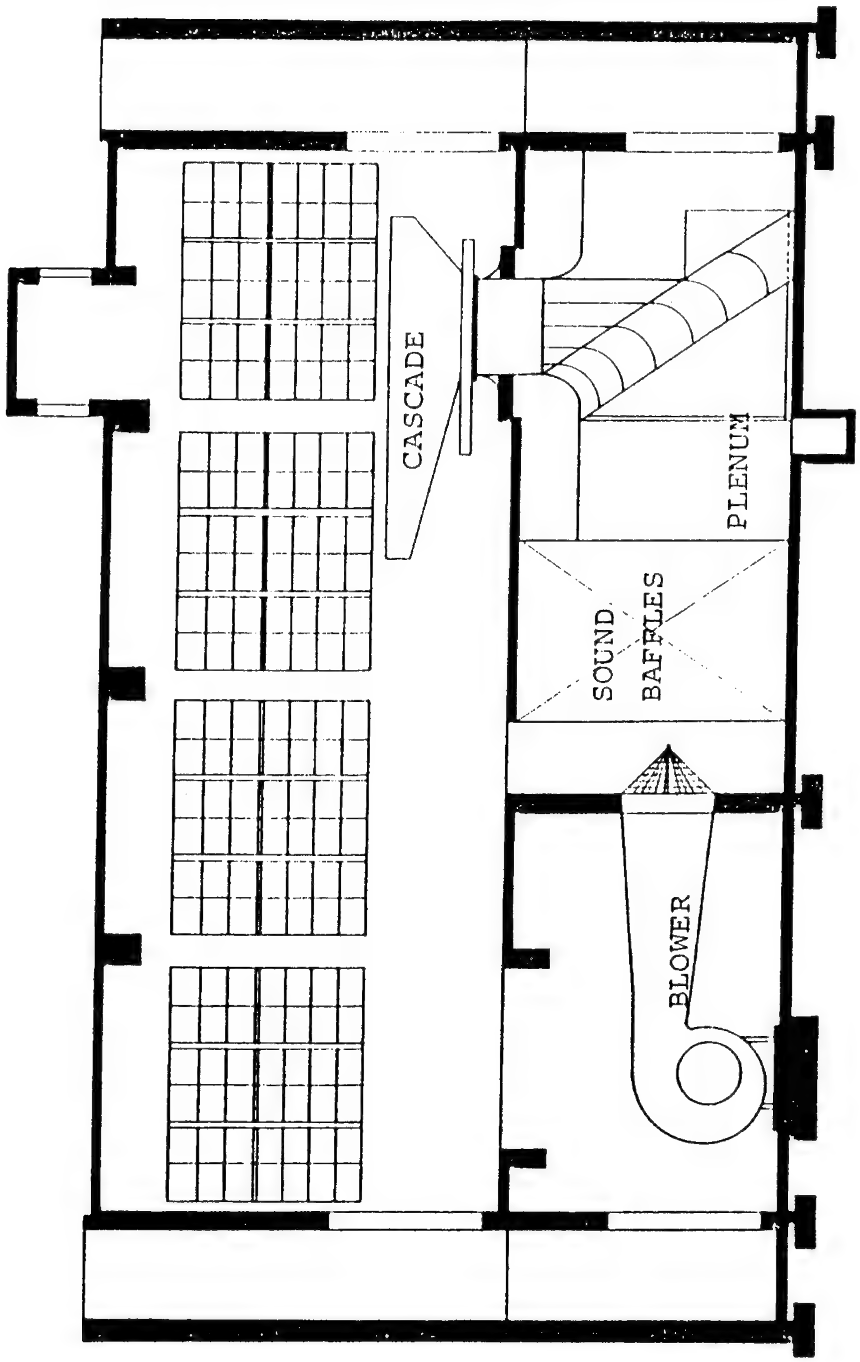


Figure 1. NPS Low-Speed Cascade Wind Tunnel Building.

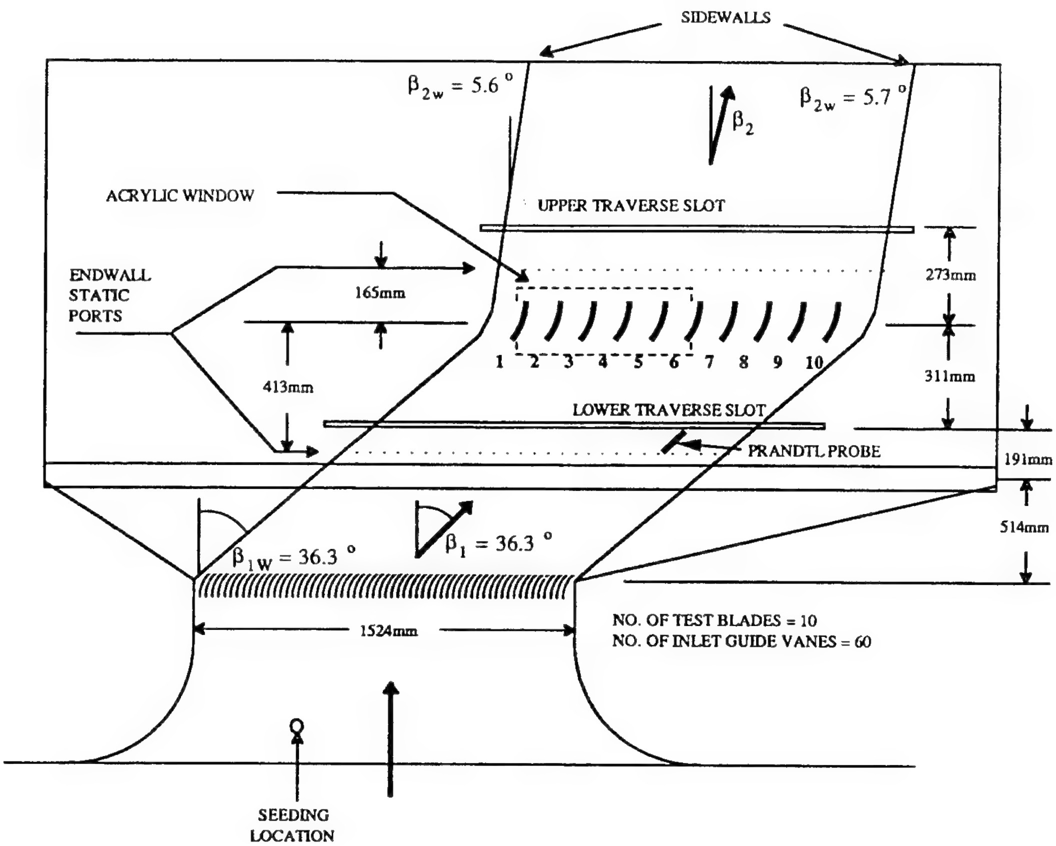


Figure 2. Low-Speed Cascade Wind Tunnel.

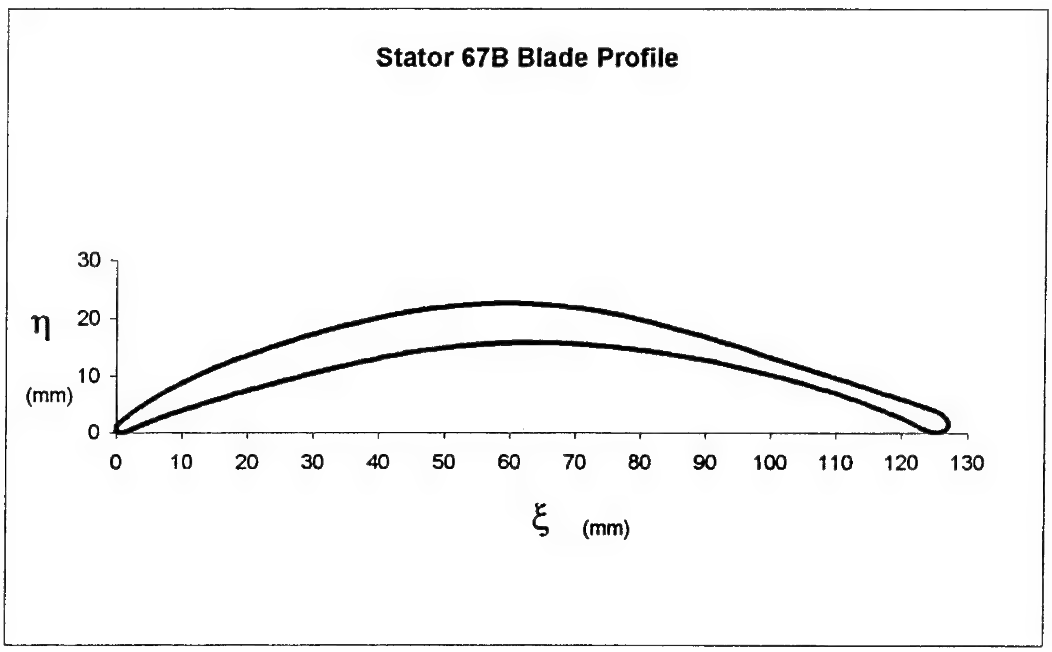


Figure 3. Stator 67B Blade Profile.

Leading Edge		Suction Surface				Pressure Surface				Trailing Edge	
ξ(mm)	η(mm)	ξ(mm)	η(mm)	ξ(mm)	η(mm)	ξ(mm)	η(mm)	ξ(mm)	η(mm)	ξ(mm)	η(mm)
0.4221	1.6596	0.4221	1.6596	63.5654	22.4993	1.4880	0.1666	63.3872	15.8060	125.0549	3.9587
0.3454	1.5824	0.7466	1.9804	64.9057	22.4186	1.8720	0.3536	64.6357	15.8072	125.2271	3.8811
0.2794	1.5062	1.0712	2.2930	66.2461	22.3138	2.2560	0.5397	65.8842	15.7957	125.3795	3.8049
0.2210	1.4300	1.3957	2.5977	67.5864	22.1843	2.6399	0.7247	67.1327	15.7704	125.5217	3.7287
0.1702	1.3538	1.7202	2.8950	68.9268	22.0292	3.0239	0.9086	68.3811	15.7302	125.6487	3.6525
0.1270	1.2776	2.0448	3.1850	70.2671	21.8481	3.4079	1.0910	69.6296	15.6742	125.7681	3.5763
0.0889	1.2014	2.3693	3.4682	71.5759	21.6457	3.7919	1.2721	70.8828	15.6010	125.8799	3.5001
0.0559	1.1252	2.8953	3.9135	72.8847	21.4189	4.3747	1.5438	72.1360	15.5113	125.9815	3.4239
0.0279	1.0490	3.4214	4.3429	74.1935	21.1691	4.9574	1.8115	73.3891	15.4055	126.0805	3.3477
0.0076	0.9728	3.9474	4.7579	75.5023	20.8976	5.5402	2.0747	74.6423	15.2840	126.1720	3.2715
-0.0051	0.8966	4.4734	5.1599	76.8111	20.6055	6.1230	2.3330	75.8955	15.1474	126.2583	3.1953
-0.0127	0.8204	4.9995	5.5503	78.1199	20.2942	6.7058	2.5860	77.1486	14.9963	126.3396	3.1191
-0.0152	0.7442	5.5255	5.9304	79.3932	19.9741	7.2885	2.8332	78.4059	14.8307	126.4133	3.0429
-0.0152	0.7391	6.2765	6.4574	80.6665	19.6386	8.0720	3.1562	79.6632	14.6519	126.4844	2.9667
-0.0127	0.6680	7.0276	6.9667	81.9398	19.2894	8.8555	3.4694	80.9205	14.4611	126.5504	2.8905
-0.0051	0.5918	7.7786	7.4587	83.2130	18.9281	9.6390	3.7742	82.1778	14.2594	126.6114	2.8143
0.0102	0.5156	8.5297	7.9337	84.4863	18.5564	10.4225	4.0722	83.4351	14.0479	126.6673	2.7381
0.0381	0.4394	9.2807	8.3922	85.7596	18.1759	11.2059	4.3647	84.6923	13.8275	126.7231	2.6619
0.0762	0.3632	10.0317	8.8345	87.0079	17.7956	11.9894	4.6531	85.9486	13.5993	126.7714	2.5857
0.1270	0.2870	11.0113	9.3880	88.2561	17.4077	12.9862	5.0158	87.2049	13.3621	126.8197	2.5095
0.1956	0.2108	11.9910	9.9173	89.5044	17.0114	13.9829	5.3741	88.4612	13.1147	126.8628	2.4333
0.2921	0.1346	12.9706	10.4250	90.7527	16.6061	14.9797	5.7279	89.7175	12.8558	126.9035	2.3571
0.3531	0.0991	13.9503	10.9137	92.0010	16.1909	15.9764	6.0769	90.9738	12.5843	126.9390	2.2809
0.4293	0.0660	14.9299	11.3861	93.2493	15.7652	16.9731	6.4211	92.2300	12.2988	126.9721	2.2047
0.5055	0.0381	15.9096	11.8448	94.4762	15.3362	17.9699	6.7604	93.4757	12.0012	127.0025	2.1285
0.5817	0.0178	17.1240	12.3975	95.7031	14.8987	19.1774	7.1646	94.7214	11.6900	127.0279	2.0523
0.6579	0.0025	18.3385	12.9336	96.9301	14.4552	20.3848	7.5617	95.9671	11.3669	127.0508	1.9761
0.7341	-0.0025	19.5530	13.4531	98.1570	14.0081	21.5923	7.9522	97.2128	11.0331	127.0711	1.8999
0.8103	-0.0051	20.7675	13.9565	99.3840	13.5599	22.7998	8.3365	98.4585	10.6901	127.0864	1.8237
0.8865	-0.0025	21.9820	14.4440	100.6109	13.1131	24.0073	8.7149	99.7041	10.3395	127.1118	1.6713
0.9627	0.0000	23.1965	14.9158	101.8351	12.6704	25.2148	9.0881	100.9356	9.9861	127.1245	1.4808
1.0389	0.0127	24.4399	15.3830	103.0593	12.2301	26.4377	9.4608	102.1671	9.6248	127.1118	1.2903
1.1151	0.0279	25.6833	15.8350	104.2835	11.7911	27.6606	9.8278	103.3985	9.2538	127.0787	1.1379
1.1913	0.0457	26.9267	16.2726	105.5077	11.3519	28.8835	10.1886	104.6300	8.8712	127.0533	1.0617
1.2675	0.0711	28.1700	16.6967	106.7319	10.9113	30.1064	10.5426	105.8614	8.4753	127.0025	0.9855
1.3437	0.0991	29.4134	17.1081	107.9562	10.4680	31.3293	10.8891	107.0929	8.0641	126.9898	0.9093
1.4199	0.1321	30.6568	17.5077	108.9738	10.0967	32.5522	11.2275	108.0961	7.7168	126.9467	0.8331
1.4880	0.1666	31.9316	17.9059	109.9914	9.7226	33.7771	11.5580	109.0993	7.3577	126.8984	0.7569
		33.2064	18.2919	111.0091	9.3460	35.0021	11.8797	110.1025	6.9862	126.8400	0.6807
		34.4812	18.6653	112.0267	8.9668	36.2270	12.1926	111.1057	6.6019	126.7714	0.6045
		35.7560	19.0255	113.0444	8.5851	37.4520	12.4966	112.1089	6.2042	126.6927	0.5283
		37.0308	19.3718	114.0620	8.2011	38.6769	12.7917	113.1121	5.7926	126.5961	0.4521
		38.3056	19.7037	114.8767	7.8922	39.9019	13.0778	113.8930	5.4623	126.4768	0.3759
		39.6119	20.0282	115.6915	7.5826	41.1350	13.3564	114.6740	5.1240	126.3752	0.3200
		40.9182	20.3364	116.5062	7.2734	42.3682	13.6245	115.4549	4.7782	126.2990	0.2819
		42.2245	20.6277	117.3210	6.9654	43.6014	13.8804	116.2359	4.4257	126.2228	0.2489
		43.5307	20.9017	118.1357	6.6594	44.8346	14.1228	117.0168	4.0671	126.1466	0.2210
		44.8370	21.1577	118.9505	6.3565	46.0678	14.3502	117.7978	3.7031	125.9942	0.1702
		46.1433	21.3953	119.5655	6.1300	47.3010	14.5611	118.3669	3.4345	125.7656	0.1194
		47.4763	21.6180	120.1806	5.9042	48.5350	14.7545	118.9361	3.1614	125.3084	0.0838
		48.8092	21.8200	120.7957	5.6775	49.7689	14.9302	119.5052	2.8820	125.0798	0.0914
		50.1422	22.0006	121.4108	5.4485	51.0028	15.0884	120.0744	2.5944	124.9274	0.1067
		51.4752	22.1587	122.0259	5.2154	52.2368	15.2293	120.6435	2.2968	124.6988	0.1448
		52.8081	22.2936	122.6410	4.9770	53.4707	15.3532	121.2127	1.9871	124.5464	0.1803
		54.1411	22.4043	123.0433	4.8173	54.7047	15.4603	121.5757	1.7825	124.3940	0.2210
		55.4884	22.4910	123.4456	4.6541	55.9437	15.5514	121.9386	1.5718	124.2416	0.2667
		56.8358	22.5527	123.8480	4.4871	57.1827	15.6268	122.3016	1.3544	124.0892	0.3200
		58.1831	22.5896	124.2503	4.3159	58.4217	15.6877	122.6646	1.1299	124.0130	0.3505
		59.5304	22.6023	124.6526	4.1398	59.6607	15.7350	123.0276	0.8979	123.9368	0.3810
		60.8777	22.5911	125.0549	3.9587	60.8997	15.7698	123.3906	0.6577	123.8606	0.4140
		62.2250	22.5566			62.1387	15.7932			123.7844	0.4470
										123.7082	0.4826
										123.6320	0.5232
										123.5558	0.5613
										123.4796	0.6045
										123.3906	0.6577

Table 1. Blade Manufacturing Machine Coordinates.

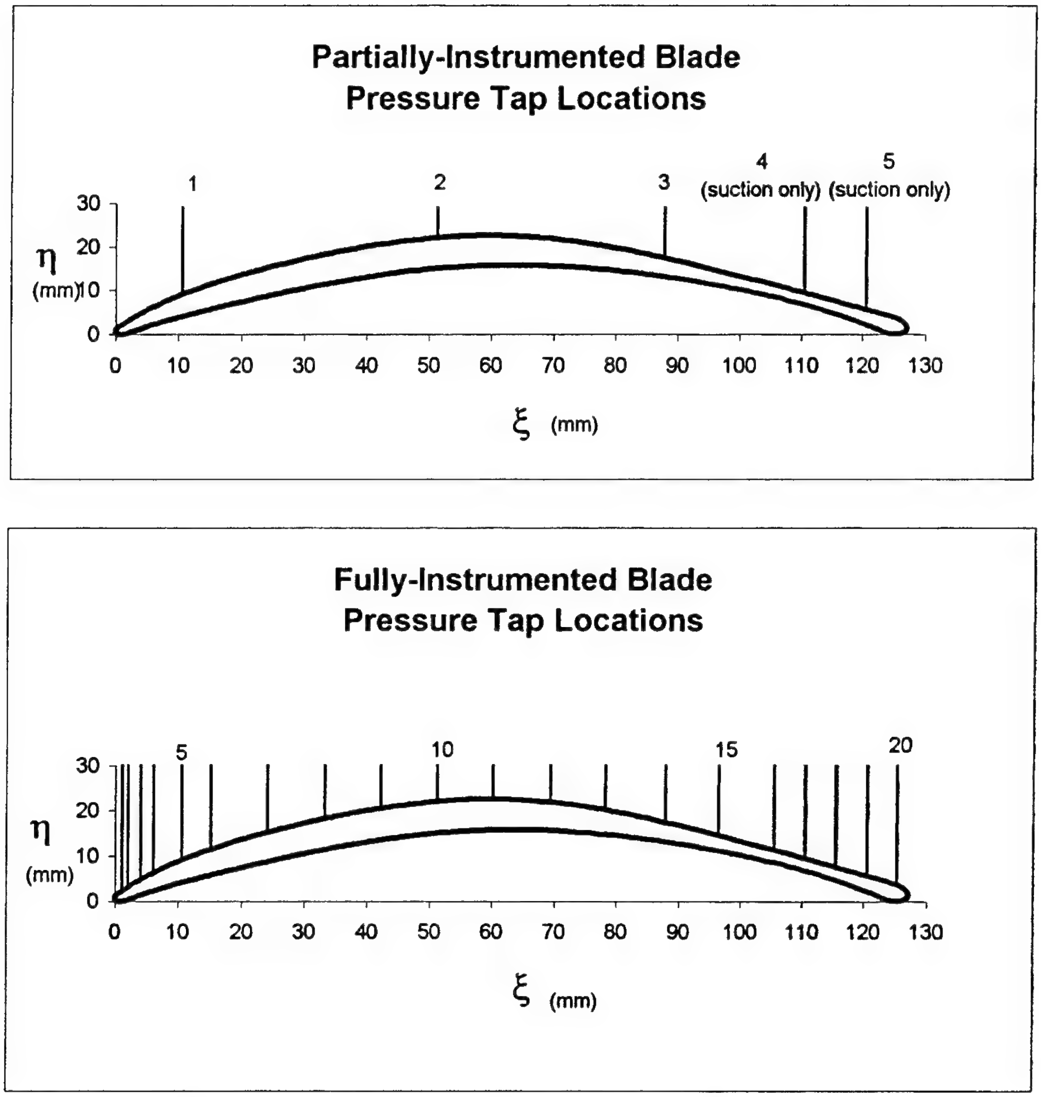


Figure 4. Instrumented Blades Pressure Tap Location.

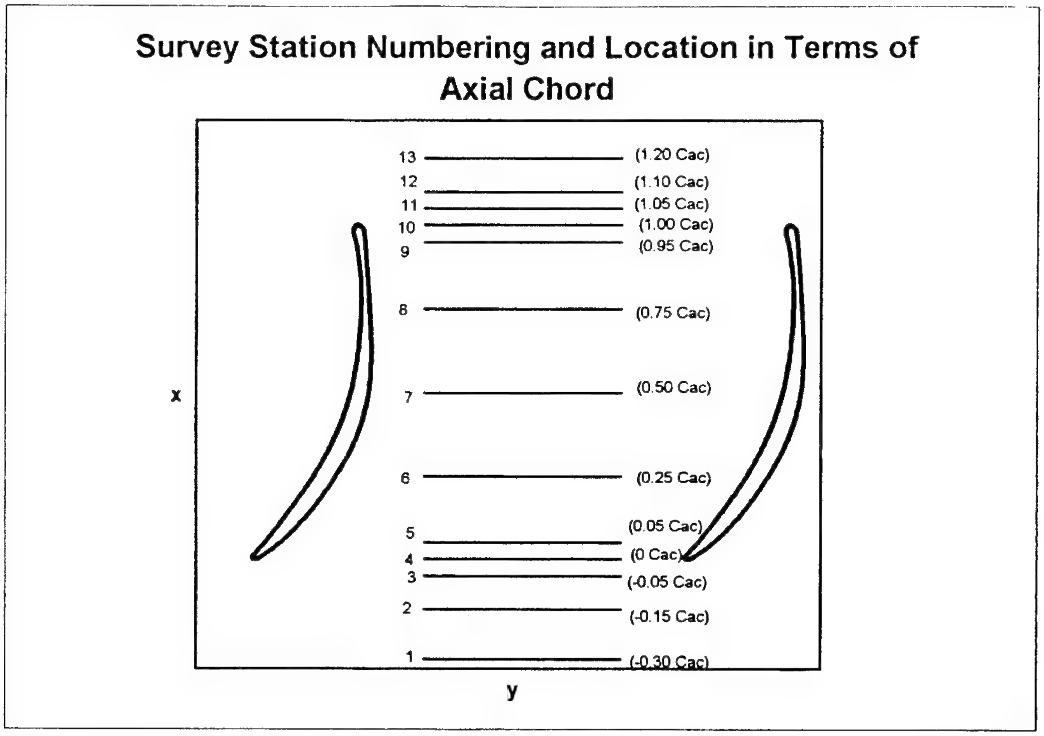


Figure 5. Survey Station Numbering and Position.

Blade Type	Stator 67B Controlled-Diffusion
Number of Blades	10
Blade Spacing	152.4 mm
Chord	127.14 mm
Solidity	0.834
Thickness/Chord	0.05
Setting Angle	16.3° ± 0.1°
Span	254.0 mm

Table 2. Test Section Data.

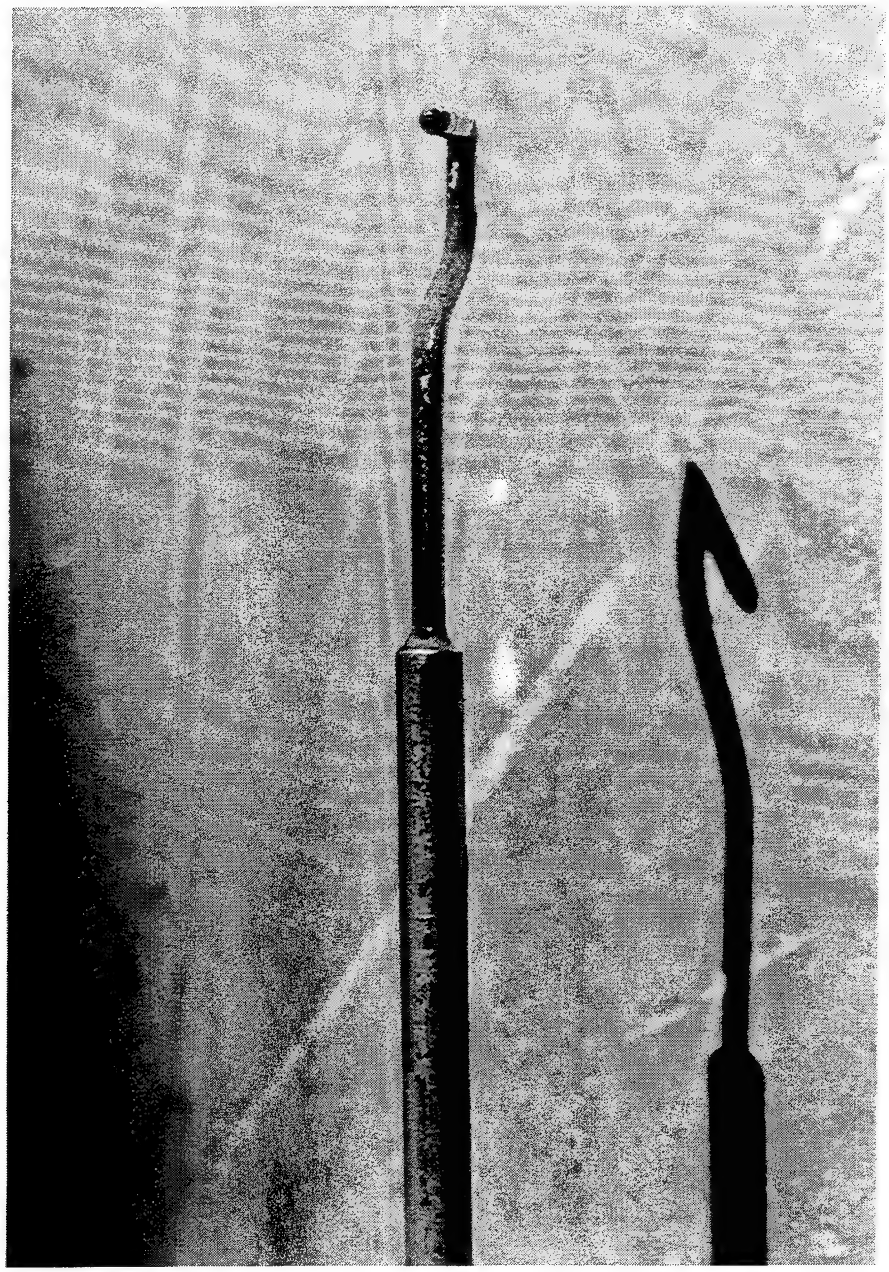


Figure 6. Five-Hole Pressure Probe.

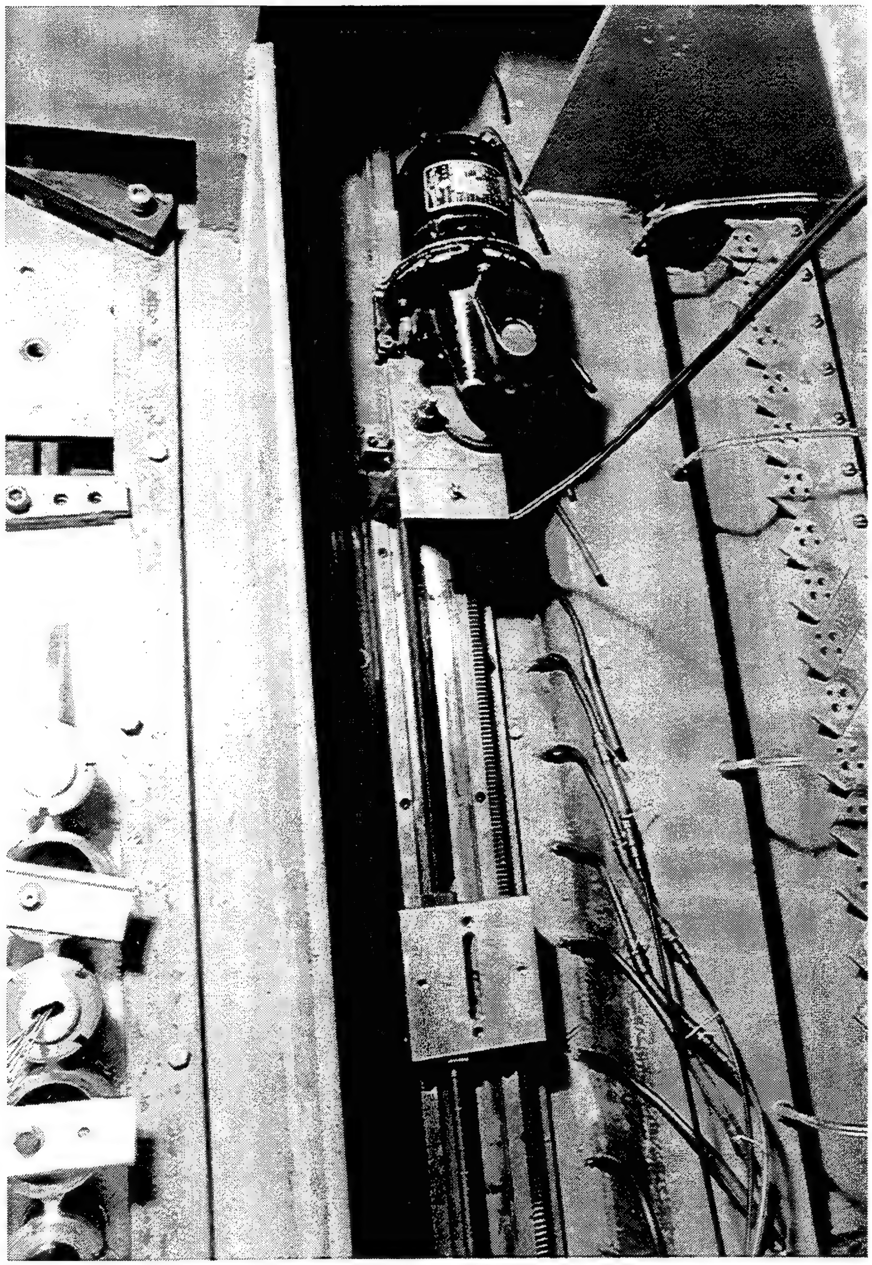


Figure 7. Five-Hole Pressure Probe Traverse Mechanism.

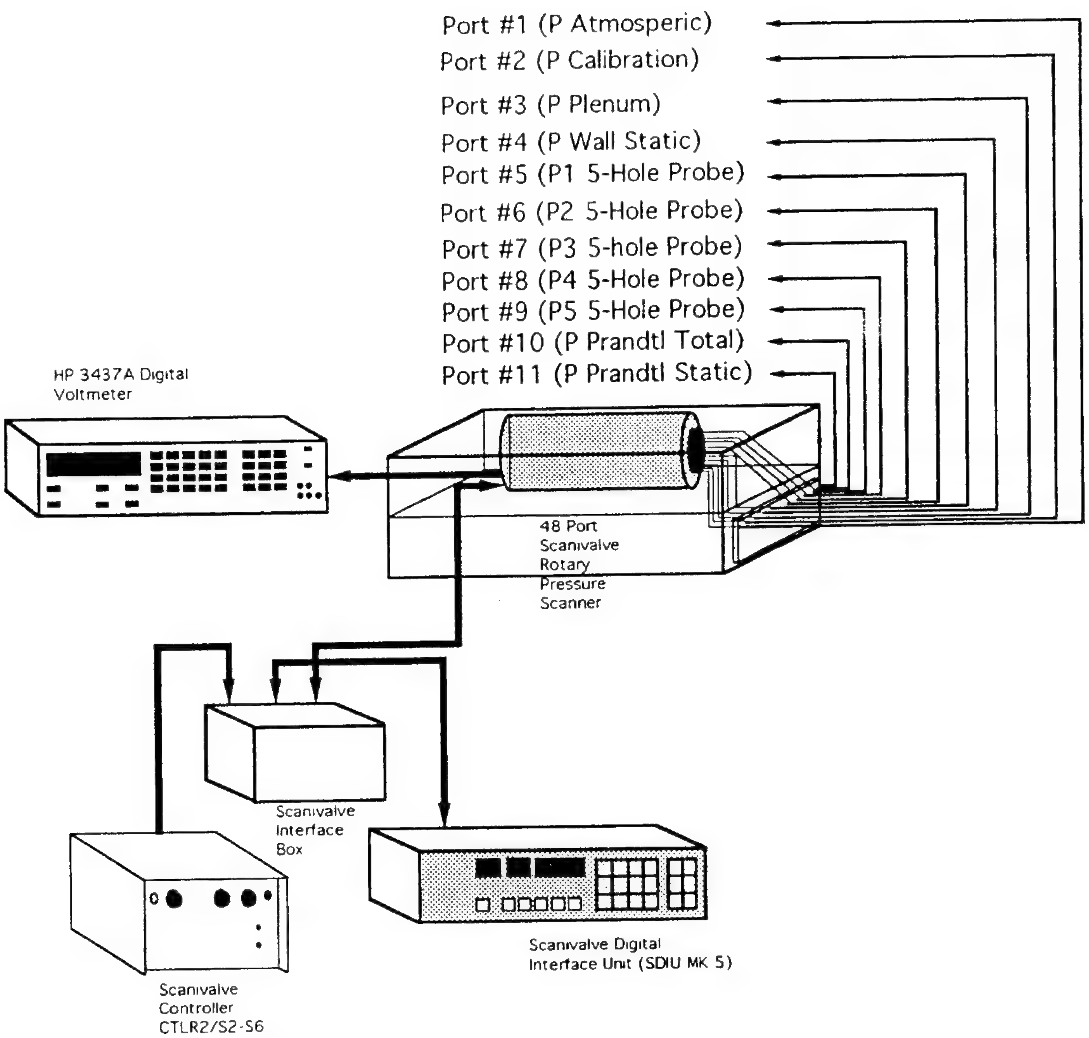


Figure 8. Manual Five-Hole Probe System.

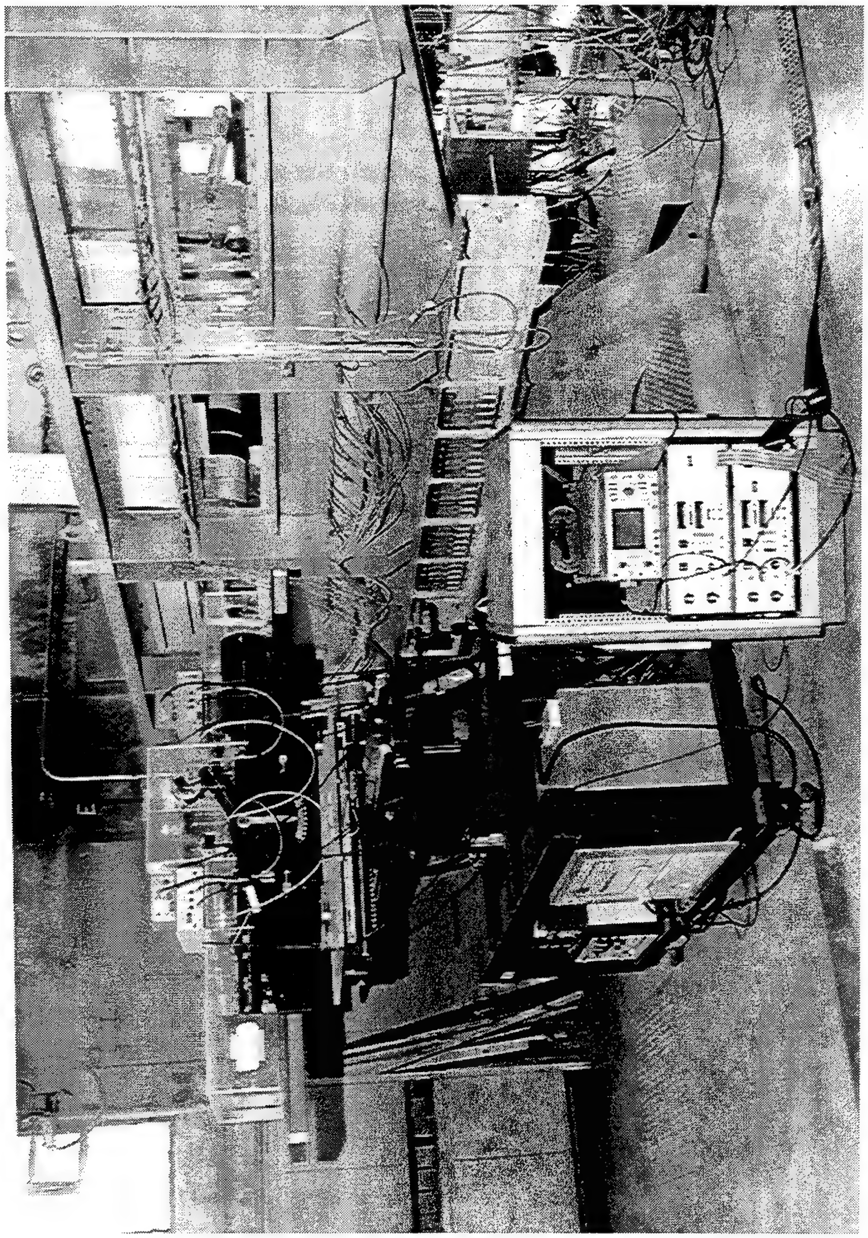


Figure 9. LDV System.

III. EXPERIMENTAL PROCEDURE

A. SURFACE PRESSURE MEASUREMENTS

The tunnel was started and allowed to reach an equilibrium operating temperature prior to all surveys. Once the tunnel reached operating temperature, the plenum chamber pressure was set and maintained at 12 inches of water. Twelve inches of water for the plenum pressure gave an average inlet Mach number of 0.22 and an average Reynolds number based on chord, Re_c, of approximately 640,000.

1. Water Manometer System

Prior to the automated data acquisition system experiments, surface pressure measurements were obtained using banks of water manometers connected to the two partially-instrumented blades. The water manometers were manually recorded to an accuracy of 0.1 inches of water. Plenum total pressure and temperature, wall static pressure, Prandtl probe total and static pressures, and local atmospheric pressure were recorded in addition to the blade pressure taps. Calculations of the coefficients of pressure, Cp, based on the Prandtl probe total and static pressures, were performed using the software Microsoft "Excel".

2. HP Automated Data Acquisition System

The HP data acquisition system was initialized, and the Scanivalve was calibrated using a water manometer prior to each experimental run. A U-tube water manometer and a regulated compressed-air supply were used as the calibration reference for both of the Scanivalve rotary pressure scanners. The five-hole probe was positioned away from the three instrumented blades to prevent wake interference. The program "ACQUIRE" sampled and recorded pressures using a Scanivalve rotary pressure scanner, and then

calculated Cp for each blade pressure tap based on the plenum total pressure, as described by Armstrong [Ref. 8].

B. FIVE-HOLE PRESSURE PROBE MEASUREMENTS

The five-hole probe traverse mechanism was mounted upstream of the test section at the tunnel lower survey location for the loss and AVDR measurements. The five-hole probe was then mounted on the traverse mechanism and centered at the blade midspan position in the tunnel. A U-tube water manometer was used with a regulated compressed-air supply to calibrate the Scanivalve rotary pressure scanner prior to making the measurements. The five-hole probe yaw transducer was also calibrated using a digital inclinometer. The five-hole probe was positioned in the pitchwise direction and aligned with the tunnel flow by balancing the probe in yaw using a U-tube water manometer prior to taking pressure data. The five-hole probe calibration coefficients developed by Armstrong [Ref. 8] were used by the data analysis.

1. HP Automated Acquisition System

The HP automated acquisition system was used to determine loss and AVDR for the blade section as outlined by Armstrong [Ref. 8]. The five-hole probe was positioned in both the lower and the upper traverse positions. Data were taken over a full passage width of 154 mm in increments of 2.54 mm, 5.08 mm and 12.77 mm, respectively, for the surveys using Armstrong's "ACQUIRE" program [Ref. 8]. The "LOSS" program was then used to calculate loss and AVDR for each combination of upstream and downstream data, as described by Armstrong [Ref. 8].

2. Manual Loss Coefficient and AVDR Measurements

The SDIU, Scanivalve controller, Scanivalve rotary pressure scanner and HP digital voltmeter were used with the five-hole probe to determine the loss coefficient and AVDR. The SDIU and controller were used to step the Scanivalve to each port for

measurements, and the pressure data were read from the digital voltmeter and recorded into a spreadsheet on a personal computer for data reduction. Plenum total pressure and temperature, atmospheric pressure, wall static pressure, and Prandtl probe total and static pressures were recorded. Probe yaw angle was also recorded. The spacing interval for the survey was 2.54 mm over a total survey width of 152.4 mm with a total of 61 data positions being recorded.

Appendix A contains the formulas which were used for the loss calculations. The calculation method was as follows. First, the dimensionless velocity coefficients, β, were determined from the five-hole probe pressure data. Next, the dimensionless velocities, X, were determined using the polynomial coefficients for the five-hole probe. The dimensionless reference velocity, X_{ref}, was determined using the pressures from the Prandtl probe. The reference flow (massflux) functions, K, were calculated for both the upstream and the downstream data. AVDR was determined using a Romberg numerical integration routine from the values of K. The loss coefficient, ω, was determined from values of C_pK, using the same type of numerical integration scheme.

C. LDV MEASUREMENTS

1. LDV Probe Volume Alignment and Reference

The need for a precise reference for the LDV probe volume necessitated the design of an alignment tool. A photograph of the tool, which was manufactured out of aluminum, is shown in Figure 10, and the tool machine drawing with dimensions is presented in Appendix B. The tool was positioned on blades 3 and 4 in the spanwise direction by placing the two end pieces against the back of the test section wall. The two endpieces secured the tool tightly against the trailing edge of both blades using the machine screw on the right-hand side, which ensured consistent positioning. Three laser alignment holes were machined in the tool's center block, each with a 0.3302 mm diameter. The laser probe volume was focused through one of these small holes, and the

automated traverse table (TSI Model 9500) was initialized to the coordinates of the hole. This alignment process was performed for each survey.

The zero reference point was determined using the blade geometry at the design setting angle. The reference point was defined by the normal intersection of two lines which were tangent to the minimum x and y points of the leading-edge ellipse of blade number 3. At this intersection, x and y were defined to be zero. The spanwise mid-point of the blade, at 127 mm, was used as the third zero reference point, and all measurements were performed at midspan.

2. Inlet Guide Vanes Adjustment

Initial LDV inlet surveys were performed over a 254 mm distance, or nearly two blade passage widths, at Station 1 to allow proper adjustment of the inlet guide vanes. The mean inlet flow angle was computed from survey data and the inlet guide vanes were adjusted until this angle converged to within 0.1 degree of the design angle of 36.3 degrees.

3. LDV Surveys

A total of 28 surveys were completed, including at least one survey of each of the thirteen stations and four boundary layer surveys. All surveys were taken by collecting 1000 data points at each location across the station, with the exception of the Station 1 surveys, where 3000 data points were taken. Figure 11 shows the location of the station surveys which will be discussed in the body of this report. A listing of all experimental runs performed is included in Appendix C.

The laser optics were configured identically throughout this study, with the 514.5 nm green beam measuring the axial (or vertical) velocity component, U, and with the 488 nm blue beam measuring the tangential (or horizontal) velocity component, V. Frequency shifting of 5 MHz was performed, as outlined by Ganaim [Ref. 10], to detect reverse flow velocities. Alignment was performed prior to each measurement using the laser alignment tool, as described above.

Ambient pressure, and plenum total pressure and plenum total temperature were recorded for each survey. The velocity at the inlet to the test section was used as the tunnel reference velocity, V_{ref}. The reference velocity was used to nondimensionalize the velocity measurements. A series of calibration surveys at six plenum pressures and temperatures were performed and a least-squares curve fit was applied to the data to determine a calibration curve for V_{ref}. A Newton-method iteration algorithm was used to determine V_{ref} for each survey using plenum total pressure, plenum total temperature and atmospheric pressure. A FORTRAN code "CALIB1" was used to calculate V_{ref}, and the FORTRAN code listing and input and output data files are contained in Appendix D.

TSI Flow Information Display (FIND) Version 4.0 software was used to acquire and analyze all LDV data. Velocity, turbulence intensity, Reynolds stress and Reynolds stress correlation coefficient information were processed using FIND, and then further non-dimensionalized using the inlet flow reference velocity, V_{ref}, to allow comparison with data taken at different LDV configurations (i.e. LDV axis not perpendicular to the optical access window).

a. Inlet Surveys

The inlet flow region was surveyed across Stations 1, 2 and 3, in the far- and near-upstream regions. The laser system was positioned horizontally for the Station 1 and 2 measurements. Station 3 measurements were conducted first with no pitch, for a region comprising 93 percent of passage width, and then the laser was pitched upward four degrees, allowing the full passage to be studied. The potential problems due to pitching and yawing of the LDV system were discussed by Hobson and Shreeve [Ref. 9]. Their analysis showed a maximum spatial error from probe volume orientation to be 0.3 mm, which is the measurement volume minimum diameter.

b. Passage Surveys

Passage surveys were conducted at Stations 4 through 10. The laser was horizontal for all passage surveys. One survey taken at Station 7 was performed with a

laser yaw angle of 4 degrees, but no pitch. Initial and final measurement boundaries were determined for the passage surveys by experimenting with the laser position until an adequate data rate was achieved. Interference degraded the laser beams when positioned too close to the blade surface, thus diminishing the data rate of the LDV system to unusably low levels. The boundaries of the surveys were set to exclude regions of interference.

c. Boundary Layer Surveys

Boundary layer surveys were performed at one station on the pressure side and three stations on the suction side of the blade. The boundary layer surveys on the suction surface of blade 3 were performed at Stations 5, 7 and 9. The boundary layer survey on the pressure surface of blade 4 was performed at Station 8. Prior to the experiment, the laser alignment tool was used to align the laser at the measurement pitch and yaw angles. The laser pitch and yaw angles used for the surveys were determined experimentally by finding the angle which allowed the closest laser probe volume positioning to the blade surface while giving an adequate data rate. The pitch and yaw angles which were used for the boundary layer surveys can be found in the summary in Appendix C. The boundary layer surveys were performed along a line normal to the blade surface at that station.

d. Wake Surveys

Wake surveys of various detail were performed at Stations 11, 12, and 13. Station 11, the near wake, and Station 13, the far wake, are presented in the next section of this report. The laser pitch angle was 5 degrees down for the Station 11 wake surveys. The laser was horizontal for the Station 13 surveys. The incremental distance between measurement positions was reduced over a series of three surveys at each of the two stations, from a full passage width and large increments to a smaller passage width and smaller increments. Again, the laser was aligned prior to each survey using the alignment tool.

D. COMPUTATIONAL FLUID DYNAMICS

A quasi-three-dimensional computational fluid dynamics program was used to analyze the flow through the cascade. The FORTRAN code, Rotor Viscous Code Quasi-3-D (RVCQ3D) Version 300, was written by Rodrick V. Chima of NASA LeRC [Ref. 12]. A 340 x 49 C-type grid was generated using the FORTRAN program "GRAPE" [Ref. 13] based on blade manufacturing dimensions [Table 1]. Appendix E contains the input data used for "GRAPE". The computational grid generated by "GRAPE" is shown in Figure 12. RVCQ3D had the option to use three different turbulence models: the Baldwin-Lomax model, the Cebeci-Smith model, and the Wilcox k-omega model; all were used. The design inlet-flow angle, Mach number, Reynolds number and pressure ratio were other inputs required to run the program. The code was run for various pressure ratios until the design inlet flow angle of 36.3 degrees and the Mach number of 0.22 were met. [See Appendix E for a sample of the input data used for RVCQ3D]. A FORTRAN program modified by Williams [Ref. 11] called "PCP" was used to extract blade surface pressure distribution data from the solution file in order to plot coefficients of pressure, Cp. The program "PCP" is also included in Appendix E.

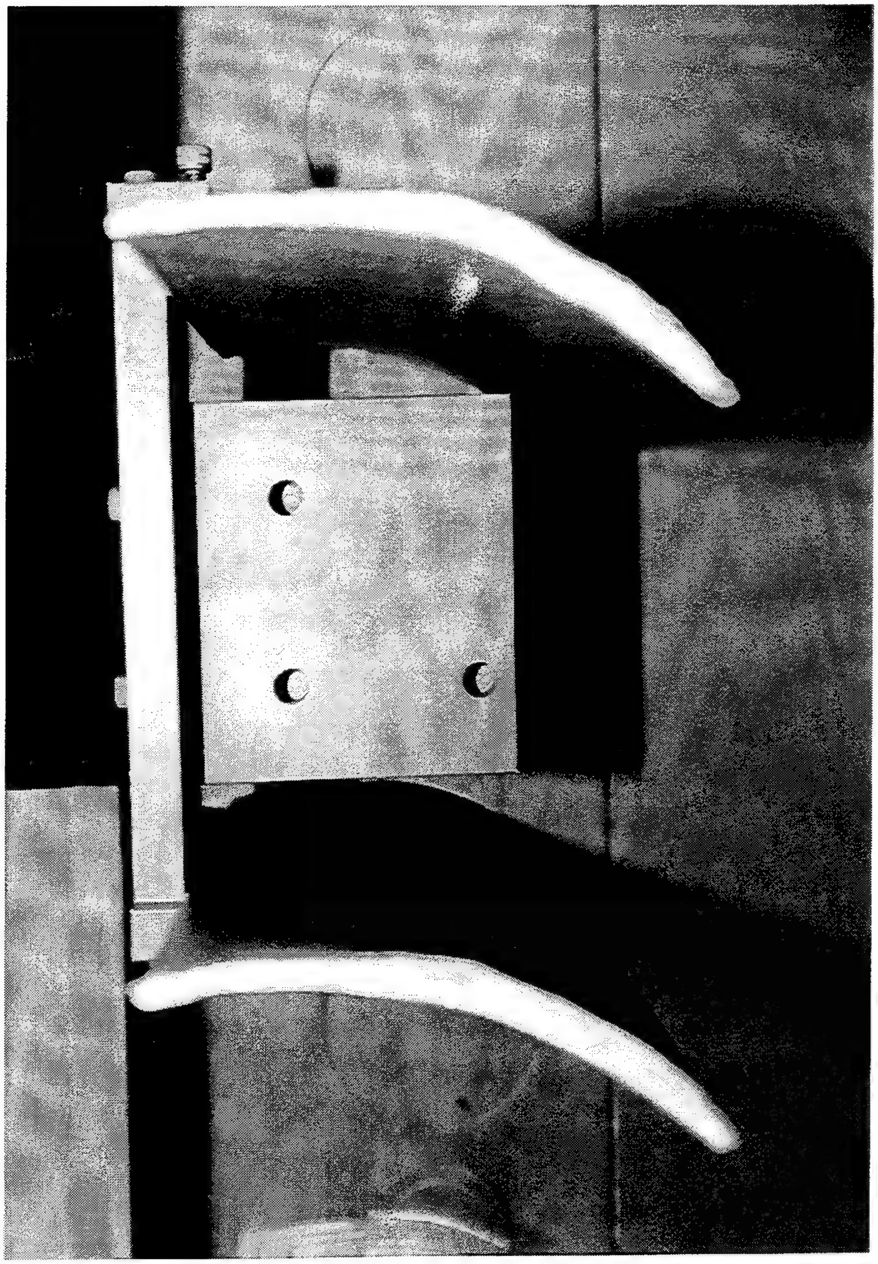


Figure 10. Laser Alignment Tool.

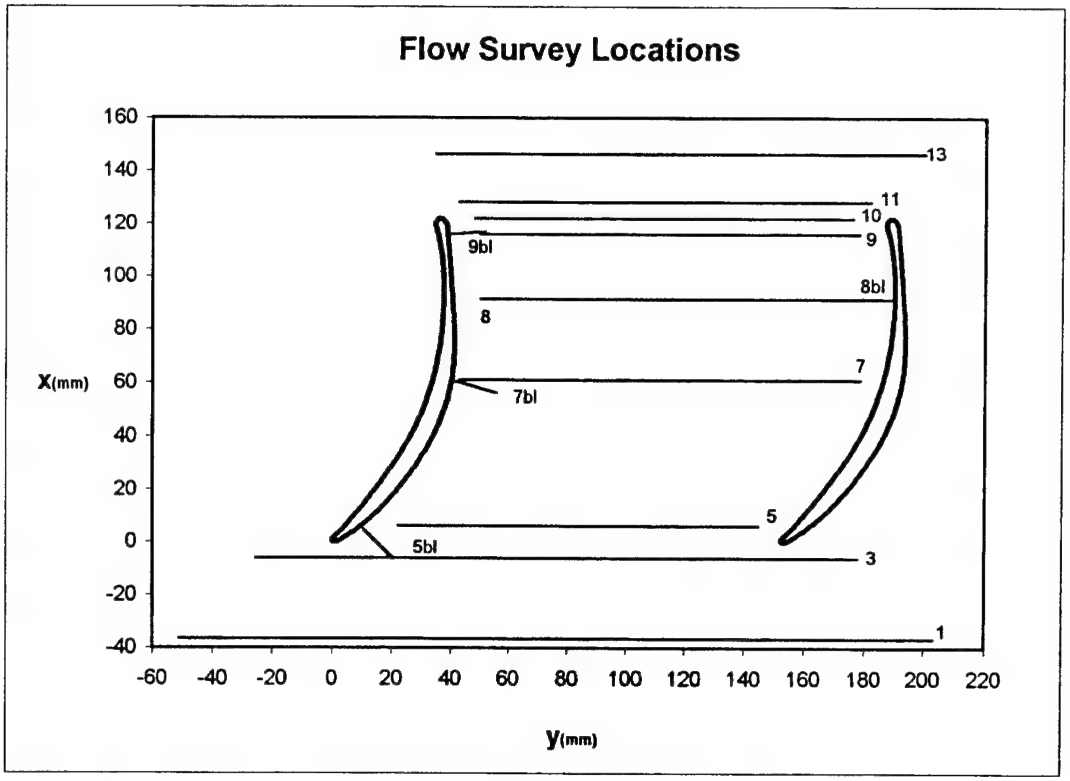


Figure 11. LDV Survey Locations.

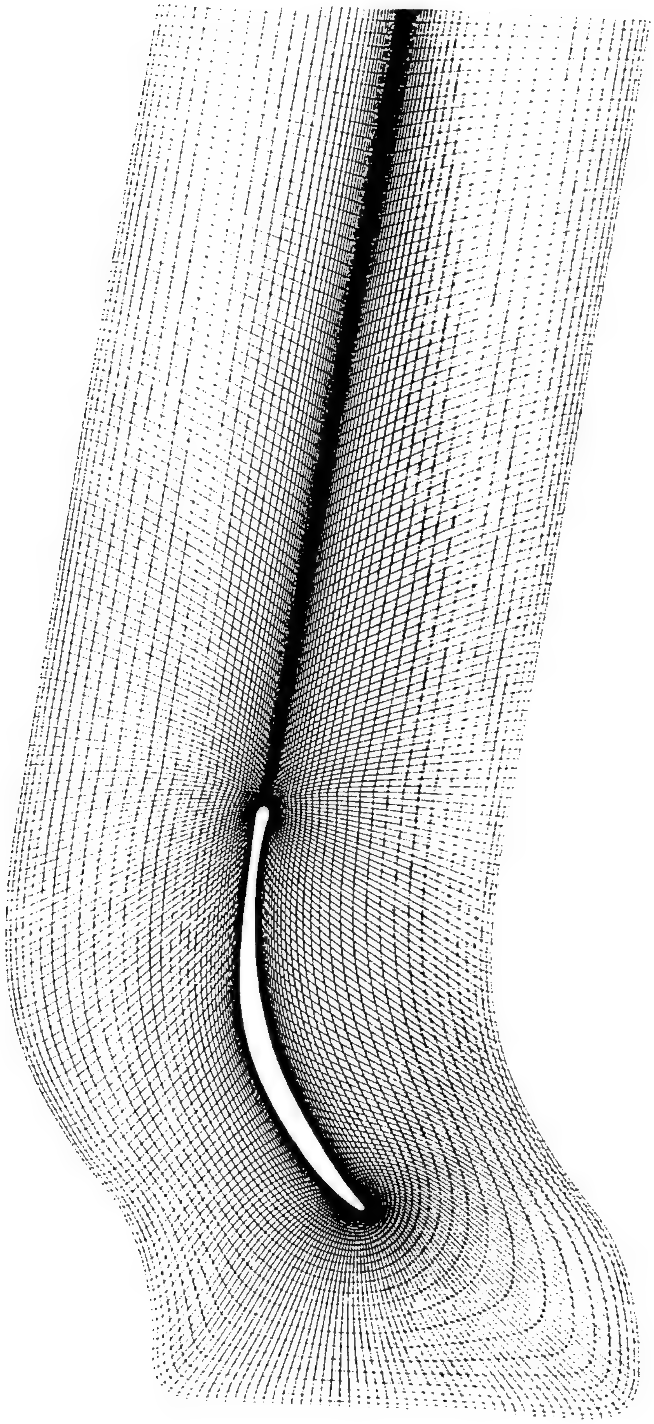


Figure 12. Stator 67B CFD C-Type Grid.

IV. RESULTS AND DISCUSSION

A. REFERENCE CONDITIONS

The results of the experimental data will be discussed in the following sections. Nominally, all surveys were performed at a Mach number of 0.22 and a Reynolds number based on blade chord of 640,000.

B. BLADE SURFACE PRESSURE DISTRIBUTION

Figure 13 shows the results of the blade surface pressure distribution measurements in terms of the coefficient of pressure, Cp, plotted along the blade chord at various positions given by the ratio ξ/c. Blades 2 and 8 were partially-instrumented with eight pressure taps each. The subscript "m" in the figure's legend denotes the manometer readings used on blades 2 and 8. Blade 6 contained 42 pressure taps, including a leading-edge tap and a trailing-edge tap and 20 taps on each of the pressure and suction surfaces. Two taps were unusable on the pressure surface of blade 6, so a total of 40 pressure measurements was made. Gelder's design intent for Stator 67B [Ref. 1] is shown plotted with the solid black line in Figure 13.

The results from the different blades and different data acquisition methods showed good agreement. The Cp calculations from both the water manometer readings and the data acquisition system produced very similar results. The Cp results for the blade pressure surface were very tightly grouped together for all three blades and both measurement techniques. The blade suction-side results showed more loosely grouped data for blade numbers 2 and 8 for the two data acquisition methods. Blade number 2 had an unusable pressure tap at 0.95 ξ/c, and also showed a partially clogged pressure tap at 0.69 ξ/c. The suction side data from blades 2 and 8 corresponded well to the data on blade 6 at all other locations.

The leading-edge pressure tap on blade number 6 showed the stagnation point to be very near the leading-edge, since the leading-edge value was Cp = 0.92. Stagnation would give unity. This was a confirmation of the design inlet-flow angle which resulted in zero incidence at the leading-edge. The trailing-edge pressure tap showed the value of Cp to be 0.10, or very close to zero.

Gelder's experimental results for the Stage 67B [Ref. 1] were similar to the present results in terms of the relation of the experimental data to the design intent. On the pressure side of the blade, Gelder's experimental Cp data were lower in magnitude than the design value, similar to the NPS results. On the suction side of the blade, the Gelder experimental data had smaller (negative) magnitudes than design until approximately 0.2 ξ/c, at which point the experimental data had larger magnitudes than the design data.

The experimental Cp profile seemed to show that the design goal of controlled diffusion was achieved. On the suction side of the blade, Cp decreased (negatively) very sharply from the leading-edge of the blade as the flow accelerated. Cp then decreased more gradually until at nearly midchord, where Cp began a near-linear increase, to arrive close to zero at the trailing-edge. The near-linear increase showed the diffusion or deceleration to be gradual, as the design goal required.

During tunnel operation, the water manometers connected to the instrumented blades showed fluctuations in the pressures. The suction side of the blade had the largest fluctuations. The occurrence of fluctuations raised the question of flow separation on the suction side. Additional measurements were needed to determine whether the flow had separated.

C. FIVE-HOLE PRESSURE PROBE MEASUREMENTS

1. Manual Loss and AVDR Calculations

The manual system was used first to make a downstream survey of 154 mm width, with an interval of 2.54 mm. A similar upstream survey was performed. The loss and AVDR were calculated using the equations discussed in the previous chapter and found in Appendix A. The AVDR was 1.023 and the loss coefficient was 0.029 using the Prandtl probe as a reference. The calculated loss coefficient was similar to Gelder's experimental result of 0.030 [Ref. 1].

. Figure 14 shows the results of the survey. The static pressure coefficient showed a rise downstream of the test section of approximately 1%. The blade wake was well-mixed out at the downstream station. The upstream flow angle was approximately 35.5 degrees and the downstream flow angle was approximately 2.5 degrees. The nondimensional velocity showed a decrease from approximately 0.10 to 0.08. These experimental results are slightly different from the LDV results since the measuring station was located approximately 2 blade chords upstream and downstream.

2. HP Automated Data Acquisition System

The HP automated data acquisition system results which were calculated by Armstrong's "LOSS" program were inconclusive. The calculated loss values ranged from -0.013 to 0.011. The AVDR values ranged from 1.04 to 1.05.

During the surveys, the digital voltmeter showed drift in both the zero and span calibration readings. Additionally, data sampling was observed to occur prior to the pressure reading from the Scanivalve transducer stabilizing after a step to the following channel. The conclusion, following these observations and from the resulting negative losses, was that the HP system results were invalid.

D. LDV RESULTS

1. Inlet Surveys

LDV measurements upstream of the test section were performed at Stations 1, 2 and 3. Stations 1 and 3 will be examined here in order to characterize test section inlet flow in both the near and far field. Station 1 was located upstream of the test section at 30% axial chord ($0.30c_{ac}$). Station 1 was surveyed over 167% of passage width, or 254 mm. Three thousand data points were taken at each position of the survey, with a total of 41 positions spaced 6.35 mm apart. Results at Station 1 in the form of velocity ratios referenced to the inlet velocity condition, V_{ref}, turbulence percentage referenced to V_{ref}, and the Reynolds stress correlation coefficient, c_{uv}, are plotted in Figure 15.

Station 1 total velocity ratio, W/V_{ref}, was nearly uniform across the passage span. Both the axial velocity ratio, U/V_{ref}, and the tangential velocity ratio, V/V_{ref}, showed a slight variation across the passage. The potential influence of the blades was felt as far upstream as 30% axial chord, which resulted in the depressions in velocity spaced one blade passage width apart. The axial turbulence, T_u, was measured to be uncharacteristically high for the position in the flow, while the tangential turbulence, T_v, was consistent at 2%. The most likely reason for the high turbulence of T_u was due to the laser optics misalignment, which was resolved during later surveys. The Reynolds-stress correlation coefficient was below 0.1, showing the flow to be random or uncorrelated.

The survey was repeated at Station 1 over a 165.1 mm width at 27 positions with 6.35 mm interval spacing, or 108% of passage width due to the turbulence discrepancy noted above, with the results shown in Figure 16. The mean velocities showed as much variation as was recorded previously. Both turbulence percentages were now of equivalent magnitude, indicating that the optics problem from the first survey was resolved. The correlation coefficient was again less than 0.1.

Station 3 was located upstream 5% of an axial chord ($0.05c_{ac}$) from the leading-edge. Two surveys were performed. For the first survey with the laser horizontal, the

survey width was only 91% of blade passage width or 142 mm, and 72 data points spaced 2 mm apart were taken. The survey did not cover the full passage due to blade interference with the two laser beams. The survey was repeated at Station 3 over a width of 203.2 mm, with 41 positions at a spacing of 5.08 mm, with the laser pitched upward 5 degrees. Figure 17 shows the overlay of the data of the two surveys, with and without laser pitch. The figure shows the repeatability of the velocity, turbulence and correlation-coefficient data for the two surveys was excellent. The proximity of the leading edge of the blades is evident in all three plots, shown by the velocity gradients near y/S = 0 and 1. The total velocity decreased to a minimum along the stream line leading to the stagnation point on the leading-edge of the blade, and increased dramatically on either side as the flow proceeded around the leading-edge. The maximum total velocity was to the right of the stagnation point, indicating the suction side of the blade. Periodicity was also shown by the repetition of the velocity distributions. Turbulence remained constant at approximately 2%, with slight increases near the stagnation streamlines. The correlation coefficient showed a peak near the stagnation points of the leading-edge on the pressure side of the blades, and remained less than 0.2 throughout the survey, indicating a slight reorientation of the turbulence around the leading-edge.

2. Passage Surveys

Passage surveys were conducted at Stations 4 through 10 in the passage between blades 3 and 4 with neither laser yaw nor laser pitch used during these surveys. Flow at Stations 5, 7, 8, 9 and 10 will be discussed in this section, and all reduced passage data can be found in Appendix C.

Figure 18 shows the Station 5 results. The velocity ratios were smooth and showed a decrease across the passage from the suction side to the pressure side of the passage. The turbulence percentages were nearly equal and maintained a value of approximately 2%. The correlation coefficient ranged from approximately -0.1 to 0.2.

The Station 7 survey results are presented in Figure 19. The velocity data in the figure showed a decrease for two points to the left of the maximum in both total and axial velocity on the suction side of the blade. The velocities then decreased gradually as the distance away from the suction surface increased. Turbulence peaked at 12% in the axial direction and decreased to 2%. Turbulence remained at 2% in the tangential direction. The correlation coefficient ranged from 0 to 0.2. These results indicated that the passage survey for Station 7 reached slightly into the boundary layer, which suggested that the boundary layer was growing in thickness, compared with Station 5.

Station 8 results are presented in Figure 20. The velocity ratios were smooth, with a slight decrease in magnitude as y/S increased. Turbulence was approximately 2%, similar to previously discussed stations. The correlation coefficient ranged from 0.1 to 0.3.

Figure 21 shows the results from the survey at Station 9. The velocity ratios remained smooth, turbulence remained at 2%, and the correlation coefficient again ranged from approximately 0.1 to 0.3. Figure 22 shows Station 10 results. The velocity ratios were similar to those at Station 9, the turbulence remained approximately 2%, and the correlation coefficient ranged from 0.1 to 0.3, as before.

3. Wake Surveys

Wake surveys were performed at Stations 11, 12 and 13. The results from Stations 11 and 13, the near and far wake, will be discussed. A series of three surveys were performed at each station, ranging in extent from a full passage width and decreasing to the width of just the wake.

Figure 23 shows Station 11 results for nearly the full passage width. The laser remained horizontal for this survey, so blade interference with the laser beams prevented a full passage-width survey. The velocity ratios are shown to be nearly uniform. Turbulence remained approximately 2% until the wake was reached, at which point the turbulence began to increase. The correlation coefficient remained below 0.3.

The laser was pitched 5 degrees down for the next two wake surveys at Station 11. Figures 24 and 25 show the results. The total velocity ratio decreased and then increased again as the wake was traversed during the survey. The axial velocity ratio was similar to the total velocity ratio. The tangential velocity ratio showed an initial increase and then decreased below zero as the wake was surveyed. The wake turbulence showed two distinct peaks in the axial direction as the wake was traversed, while the tangential direction showed a single peak. The maximum axial turbulence was 18%, and the maximum tangential turbulence was 16%. The correlation coefficient started at a magnitude of 0.2 and became -0.2 as the wake was traversed, and returned to a value of approximately 0. Figure 26 shows the results of the two Station 11 wake surveys plotted together. The data of the two surveys correlated very well, as shown by the close overlay.

Station 13 was surveyed over three different ranges from an entire blade passage width to just the width of the wake. Figure 27 shows the first survey over more than the passage width. The velocity ratio showed a decrease through the wake, giving an indication of the necessary width for the following survey. The turbulence was approximately 2% over the passage, until the wake was encountered. In the wake, turbulence increased to approximately 14%. The correlation coefficient decreased from 0.2 to -0.2 through the wake, and remained approximately 0.1 outside of the wake.

Figures 28 and 29 show more detailed wake surveys at Station 13. The velocity ratios again showed a decrease as the wake was traversed, and then an increase. The axial turbulence in the wake showed two peaks, similar to the Station 11 results, and had a maximum magnitude of 14%. The tangential turbulence showed a single maximum peak, similar to the Station 11 results, with a maximum magnitude of 12%. The correlation coefficient went from 0.2 to -0.2 in the wake, while remaining at approximately 0.1 outside of the wake. Figure 30 shows the two Station 13 wake surveys plotted together. The data correlated well and only the axial turbulence, T_u, showed a slight difference in value on the right side of the wake.

The axial turbulence results in Figures 26 and 30 are of interest. While both stations show two peaks in T_u, Station 11 showed the maximum peak to be located on the left side of the wake, while Station 13 showed the maximum magnitude to be located on the right hand side. While asymmetry in the wake turbulence was measured in the wake of the Stator 67A cascade [Ref. 5], a reversal of the asymmetry from one side to another was not previously observed.

4. Boundary Layer Surveys

Boundary layer surveys were performed at four stations, normal to the surface of the blade at the specified station. Station 5, 7 and 9 were surveyed on the suction side, while Station 8 was surveyed on the pressure side. A combination of laser pitch and yaw was used in order to position the LDV probe volume as close to the blade as possible.

A total of three surveys were performed at Station 5 with three different combinations of laser yaw and pitch. The combination which worked best was a yaw of 5 degrees and a pitch of 0 degrees, due to beam reflection from the cascade wall and off the brass shims on the far endwall. The results of the boundary-layer survey at Station 5 are plotted in terms of the ratio of distance from the wall and blade chord, and are shown in Figure 31. The velocity ratios showed only a slight decrease on the left side, at the minimum y/S value, which corresponded to the edge of the boundary layer. The turbulence was a maximum for approximately 4 survey points at the boundary layer edge, which decreased to approximately 2% away from the boundary layer. The correlation coefficient was a maximum near the blade surface, and decreased to 0.1. No data could be taken close to the blade.

The results of the boundary-layer survey taken at Station 7 are shown in Figure 32. The velocity ratios showed a low flat area near the blade, which then rose to near freestream values. The axial turbulence started near 12%, rose to a peak of 40% and then began to decrease near the freestream. Tangential turbulence remained approximately 2%. The correlation coefficient fluctuated from -0.1 to 0.1 for the survey. The high level of

axial turbulence suggested that the flow had separated in the vicinity of Station 7. The boundary layer data, along with the fluctuating pressure noted during Cp measurements, and the passage survey results, collectively indicated flow separation.

The results from the Station 8 pressure-side boundary-layer survey are shown in Figure 33. The abscissa was plotted in reverse order, since the pressure side of blade 4 was on the right-hand side of the survey passage. The velocity ratios showed a decrease in the total velocity for the last seven points of the survey, on the right side. The turbulence increased for the seven positions near the blade, to a maximum of 6%. The correlation coefficient showed an increase from approximately 0.3 to 0.4 in the boundary layer.

Station 9 boundary layer results are plotted in Figure 34. This survey was performed on the suction side of the blade. The velocity ratio showed a decrease for the ten points near the blade surface, and the turbulence increased in both the axial and tangential direction as the blade surface was approached. The boundary layer profile suggested that the flow had reattached itself to the suction surface prior to Station 9. The correlation coefficient decreased below 0 in the boundary layer, and then increased to 0.1 in the passage.

5. Combination of Boundary Layer and Passage Surveys

Two Station 7 survey results are presented together in Figure 35. The passage survey at Station 7 indicated the boundary layer was thicker than at other stations, allowing a few data points to be taken inside the boundary layer without laser pitch or yaw. The boundary layer survey at Station 7, performed along a path normal to the blade surface at Station 7, showed that a large region of separation existed. In order to study the flow close to the blade surface with the same reference as the passage surveys, the laser was yawed to perform another passage survey at Station 7. Data from this survey with the laser yawed was plotted with the Station 7 passage survey data [from Figure 19], in Figure 35. The velocity data in the figure show a flat region for both total and axial

velocity in the boundary layer, and then a rapid rise to freestream conditions. Turbulence peaked at 24% in the axial direction, and remained at 2% in the tangential direction. The correlation coefficient was erratic in the boundary layer, ranging from -0.1 to 0.1. The correlation coefficient then settled to a positive value of 0.2 outside the boundary layer.

Hobson and Shreeve [Ref. 9] located separation near the leading edge of Stator 67A blades in the NPS cascade. The velocity profile at Station 3 from Hobson and Shreeve [Ref. 9] had a similar shape to the Stator 67B Station 7 velocity profile [Figure 35]. The turbulence results from their measurements and those at Station 7 are quite similar. The results of the combined data in Figure 35, Cp observations, and the boundary layer data all indicate that flow separation was present on the suction side at Station 7.

The passage survey data and the boundary layer data at Stations 8 and 9 are plotted in Figures 36 and 37, respectively. The results were of interest since the passage survey was nearly normal to the blade at those stations. The boundary layer extent was evident in these figures. The velocity ratios decreased in the boundary layer and the turbulence increased significantly.

E. CFD RESULTS

Rotor Viscous Code Quasi-3-D was run using three turbulence models. The pressure ratio, prat, was iterated upon until the inlet-flow angle converged to within 0.02 degrees. The CFD predictions are plotted in Figure 38 together with the experimental results for the pressure distribution. Table 3 gives the values of the pressure ratio, prat, which yielded design inlet-flow angle when the CFD code was used with the three different turbulence models.

All computed results showed a sharp acceleration on the suction side initially, and then a gradual deceleration for most of the rest of the suction side. Near $\xi/c = 0.70$ on the suction side, the code predicted a slight re-acceleration. These CFD results for the suction side did not match the experimental data which showed a more gradual acceleration,

peaking at approximately $\xi/c = 0.40$, and then a near-linear deceleration. The predicted results on the pressure side of the blade compared quite well with the experimental data.

The Wilcox k-omega turbulence model had the capability to modify the freestream turbulence, which was computationally changed from 0.02 to 0.04. The result from an increase in turbulence from 0.02 to 0.04 showed no significant change in the predicted Cp results.

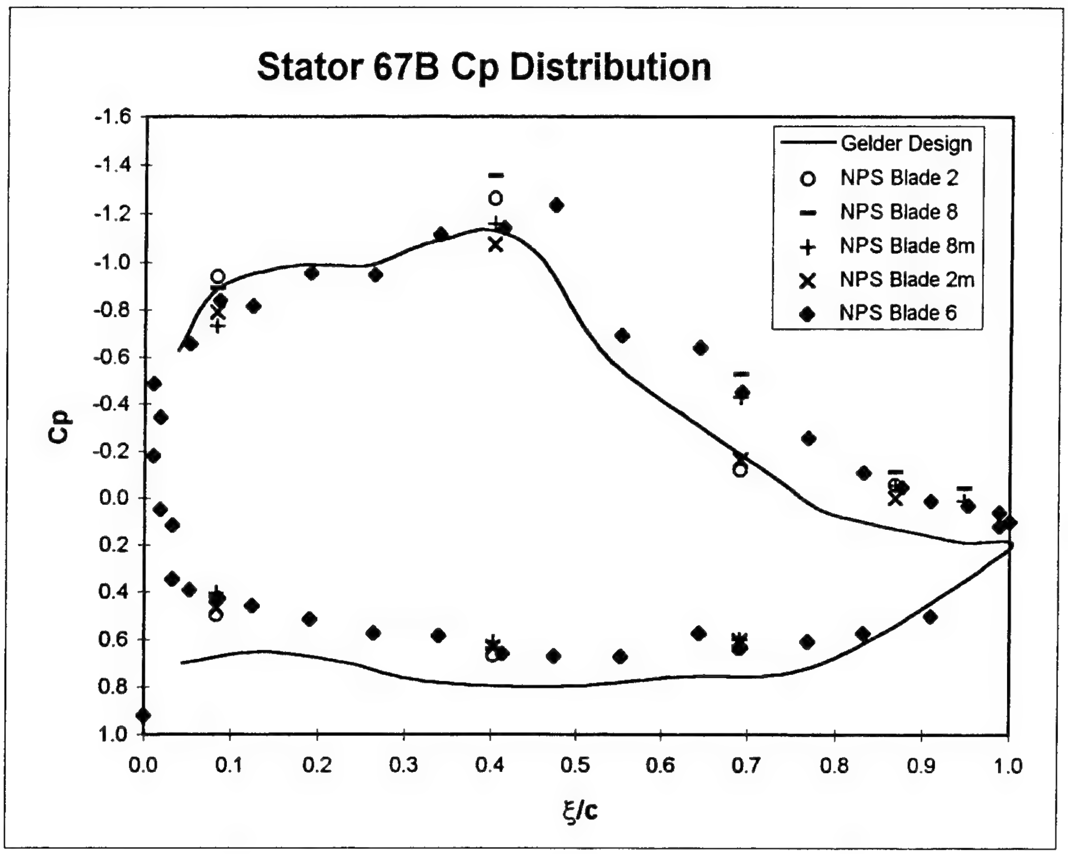


Figure 13. Experimental Cp Distribution.

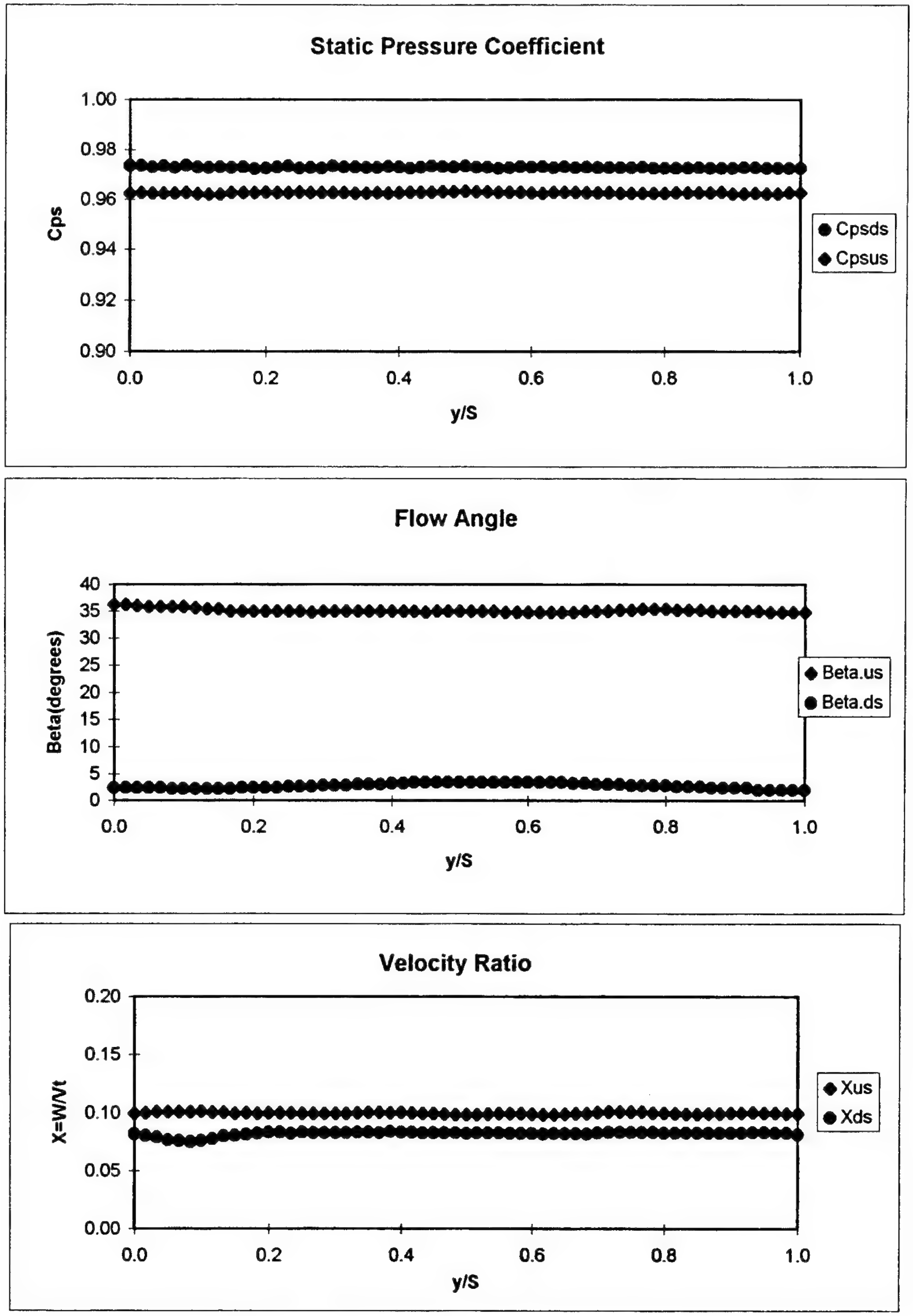


Figure 14. Manual Loss Survey Results.

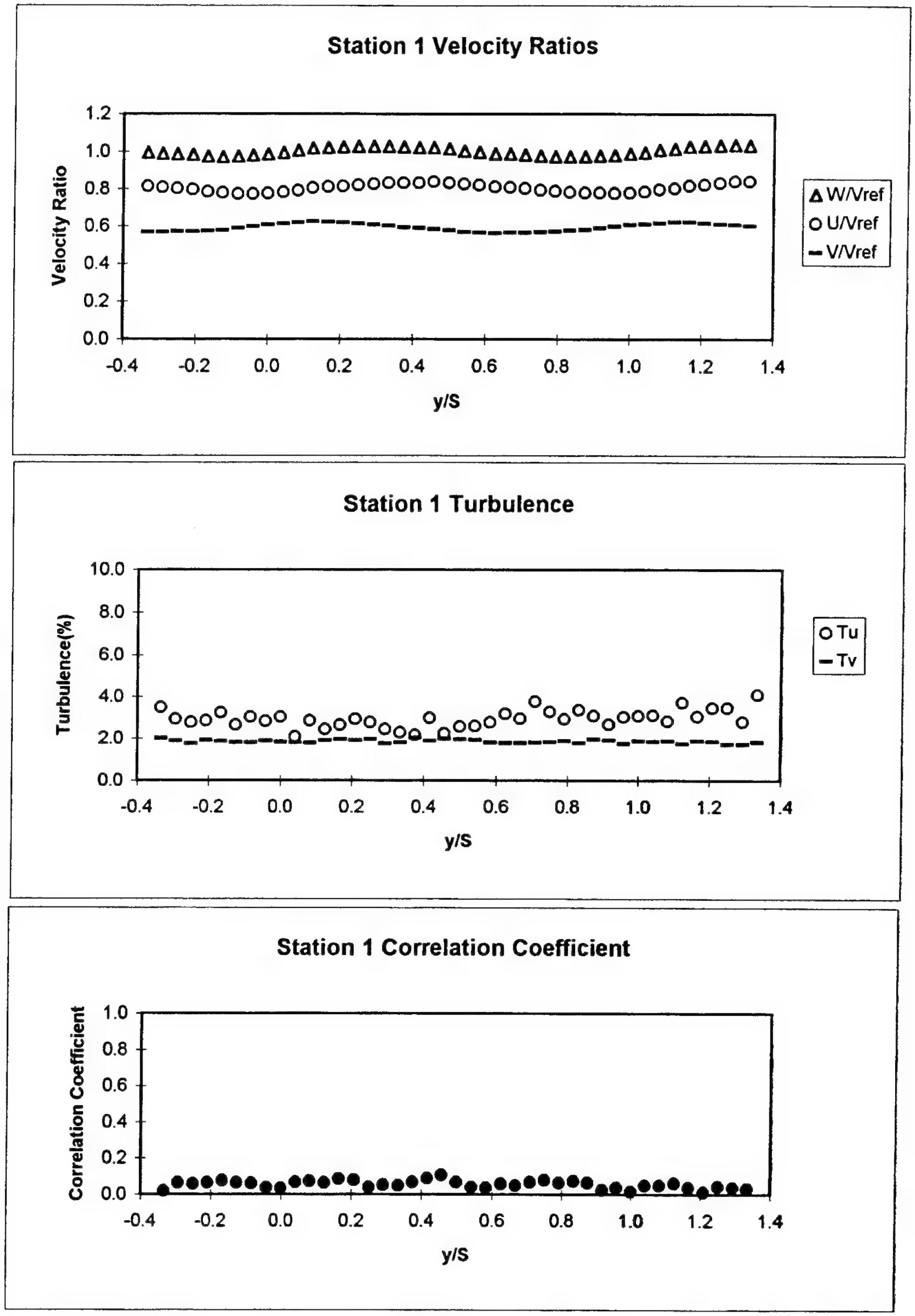
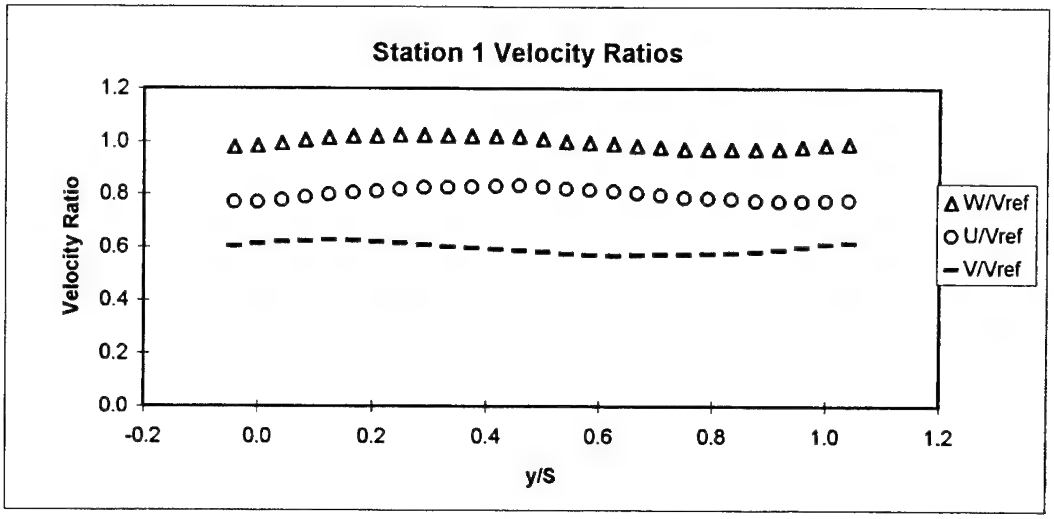
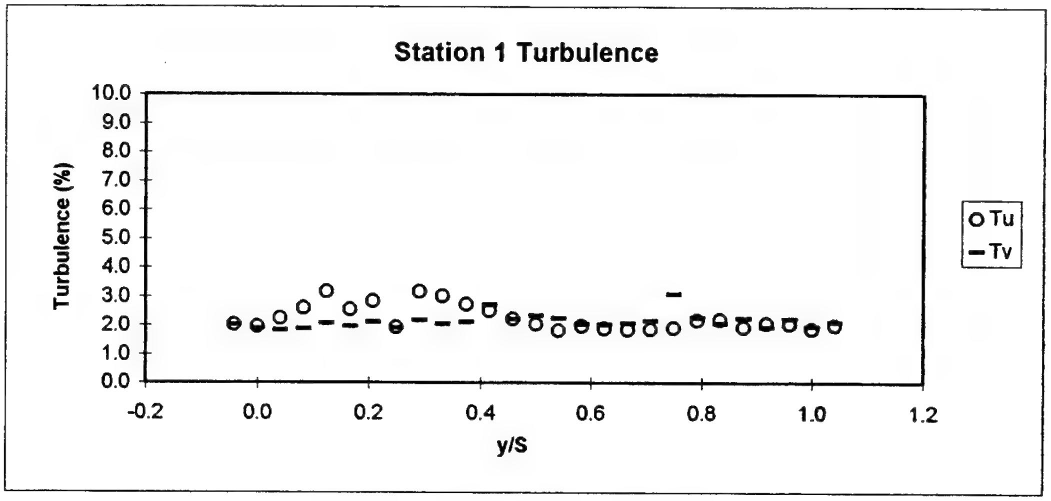


Figure 15. Station 1 Survey Results for 167% Passage Width.





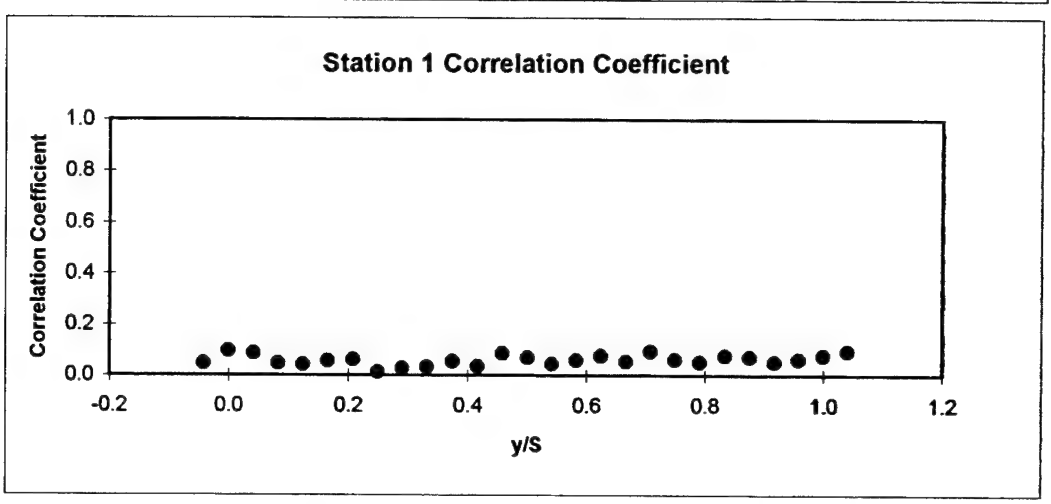


Figure 16. Repeat Station 1 Survey Results for 108% Passage Width.

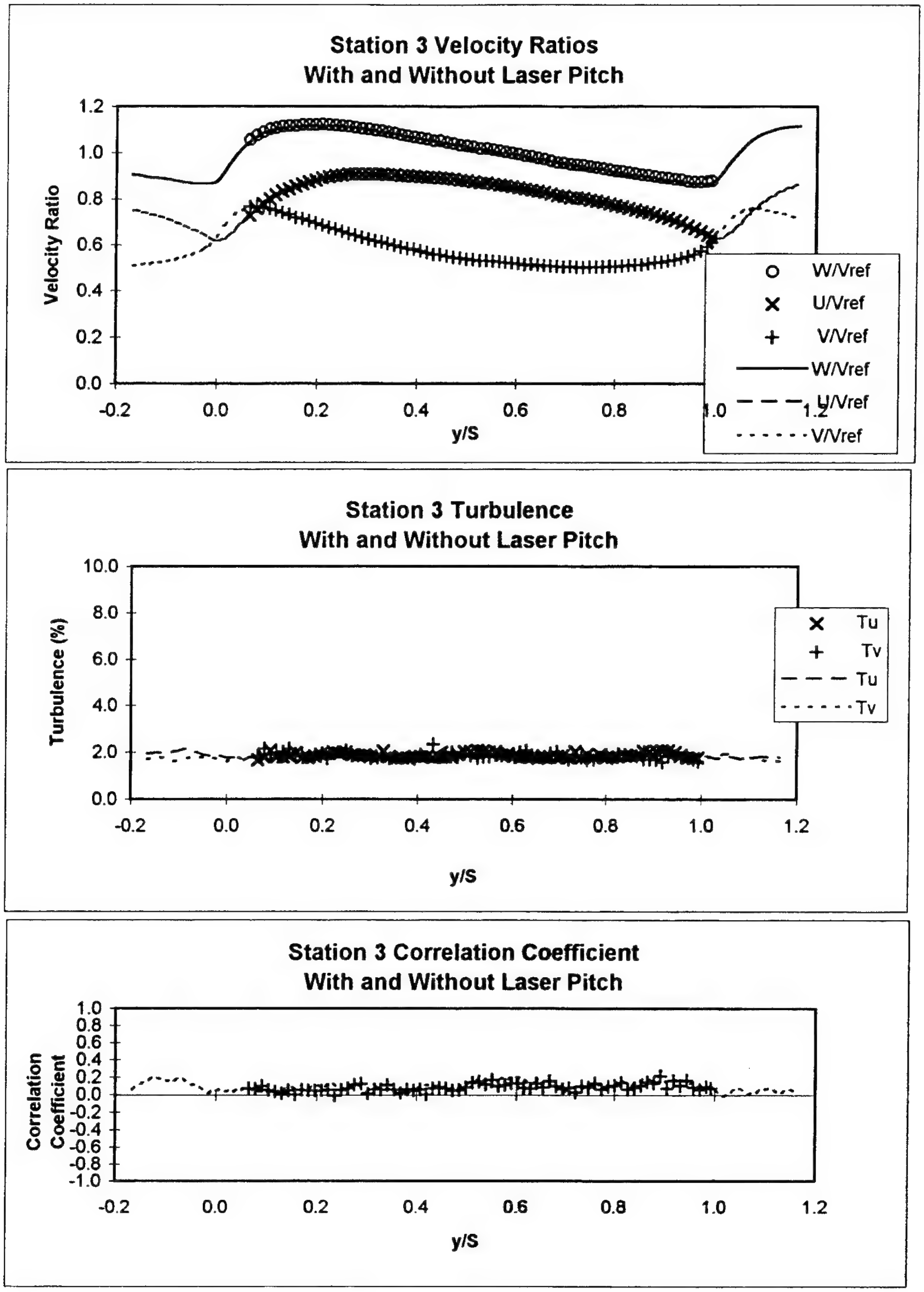


Figure 17. Station 3 Survey Results With and Without Laser Pitch.

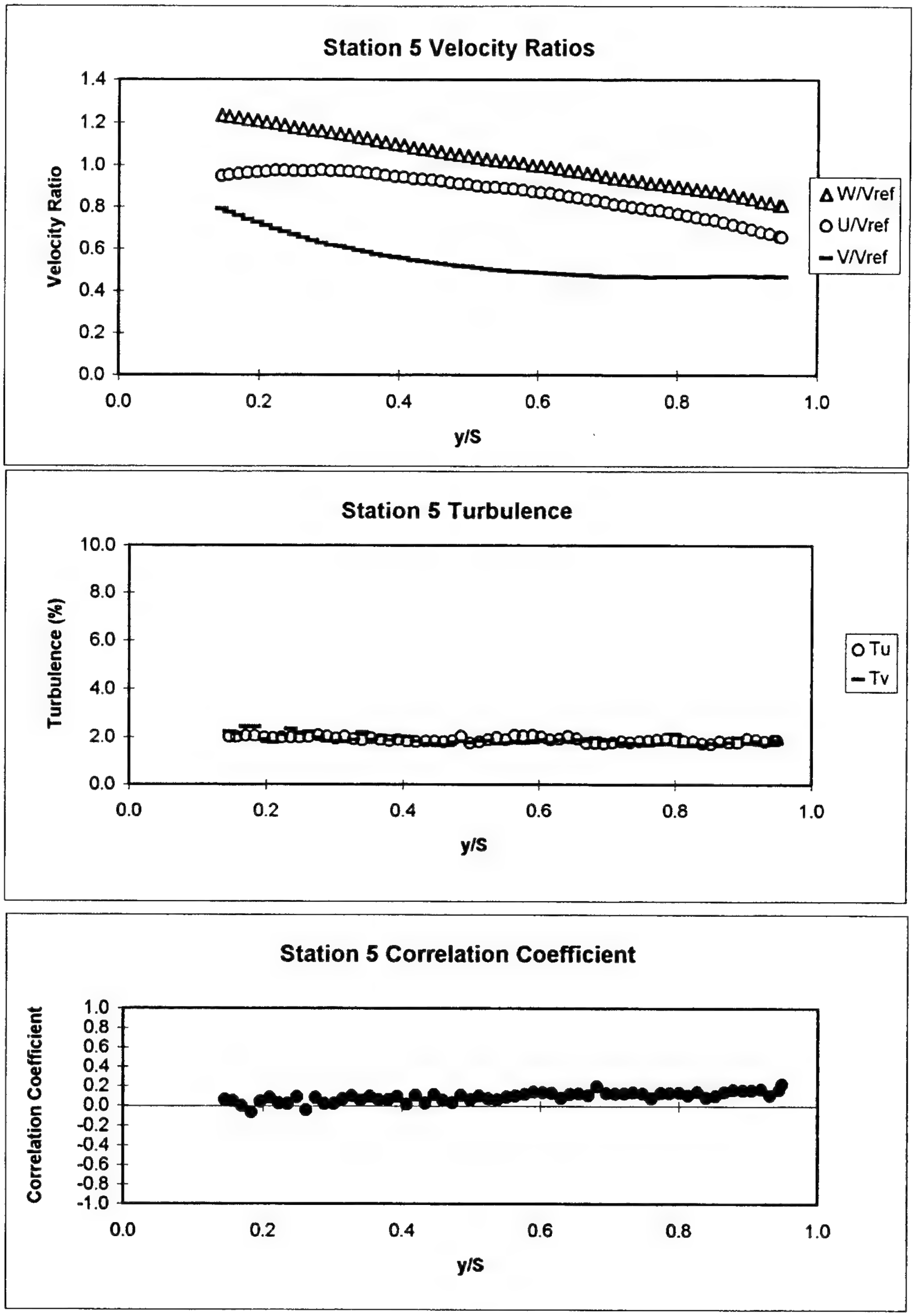


Figure 18. Station 5 Passage Survey Results.

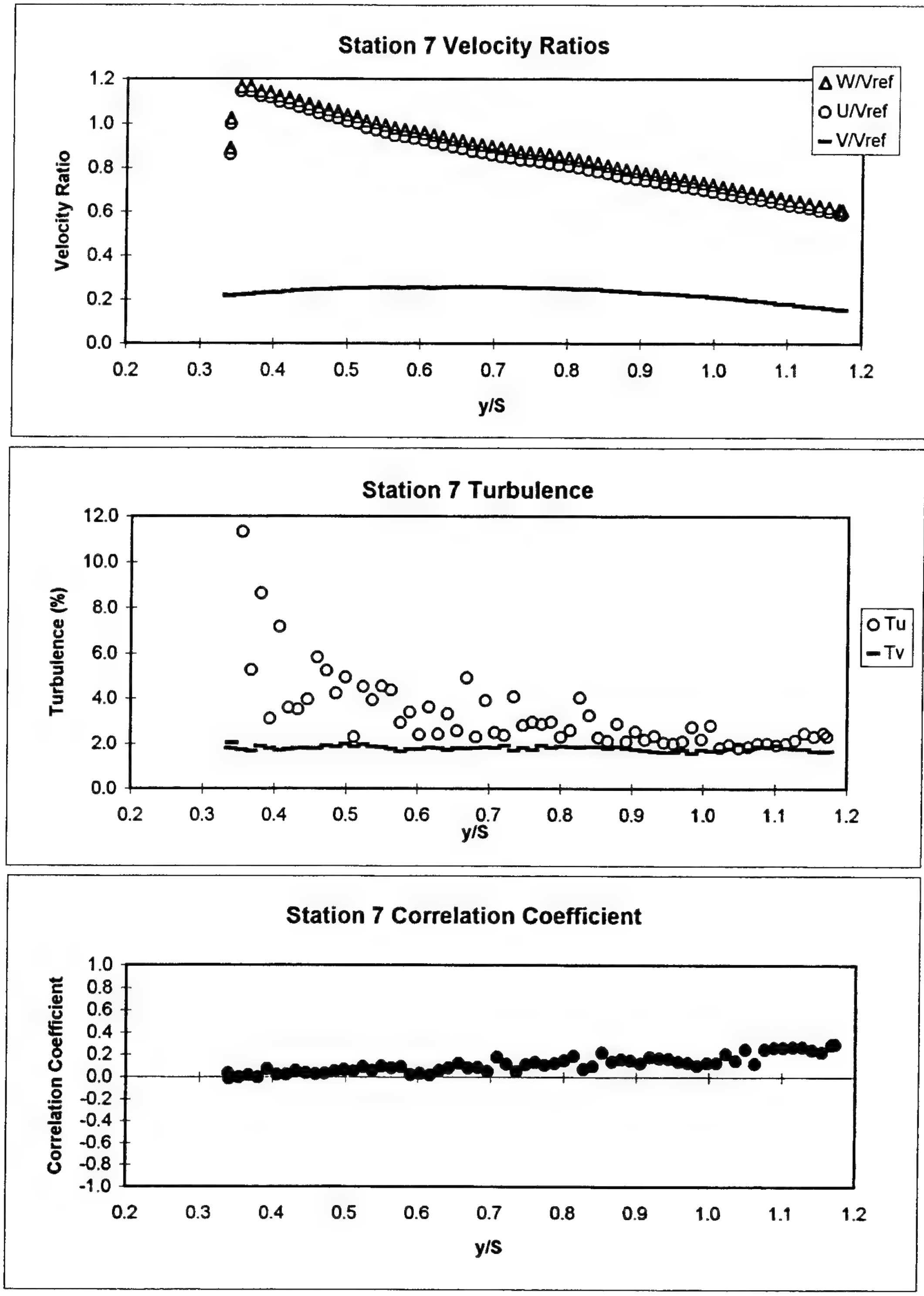


Figure 19. Station 7 Passage Survey Results.

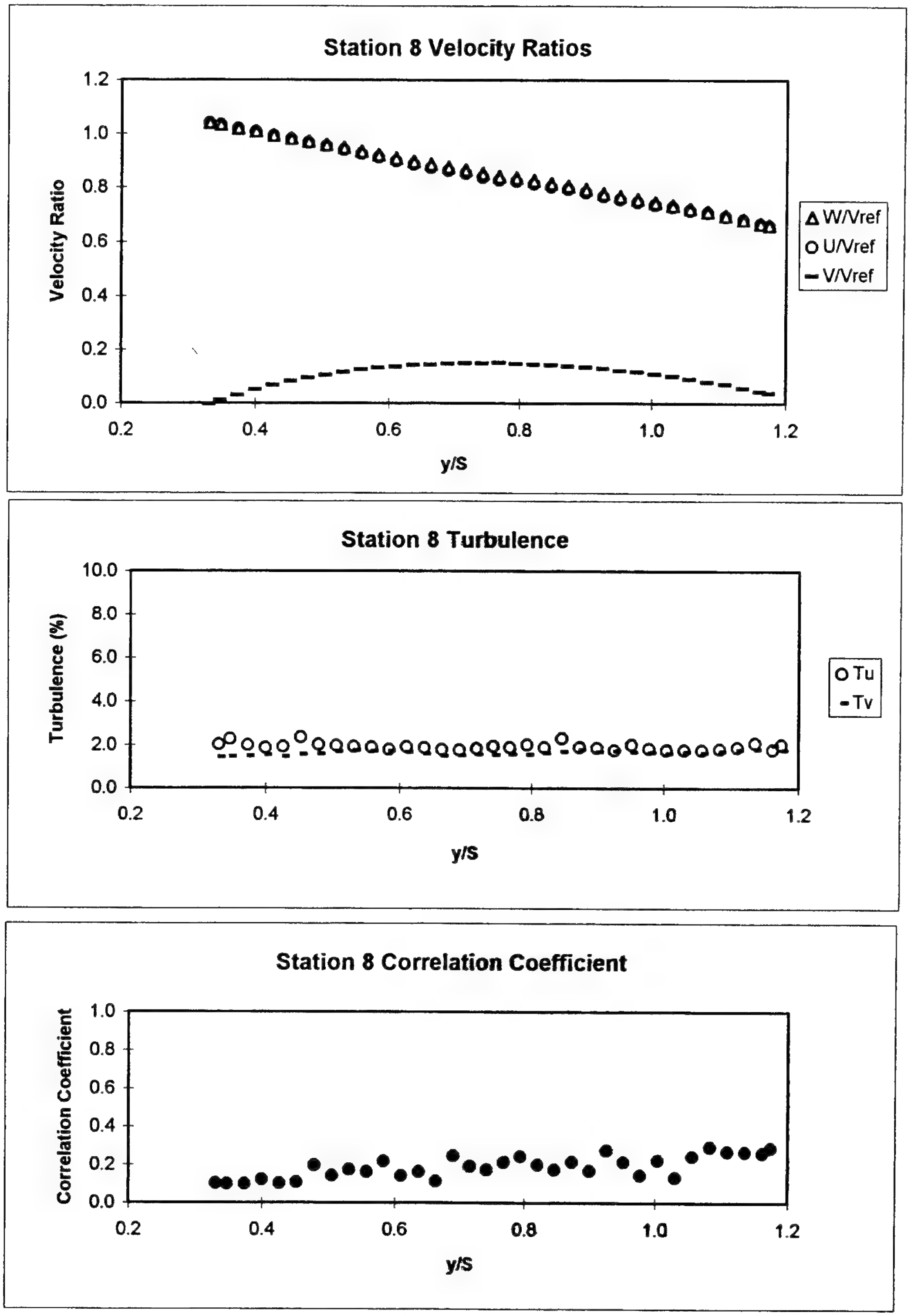


Figure 20. Station 8 Passage Survey Results.

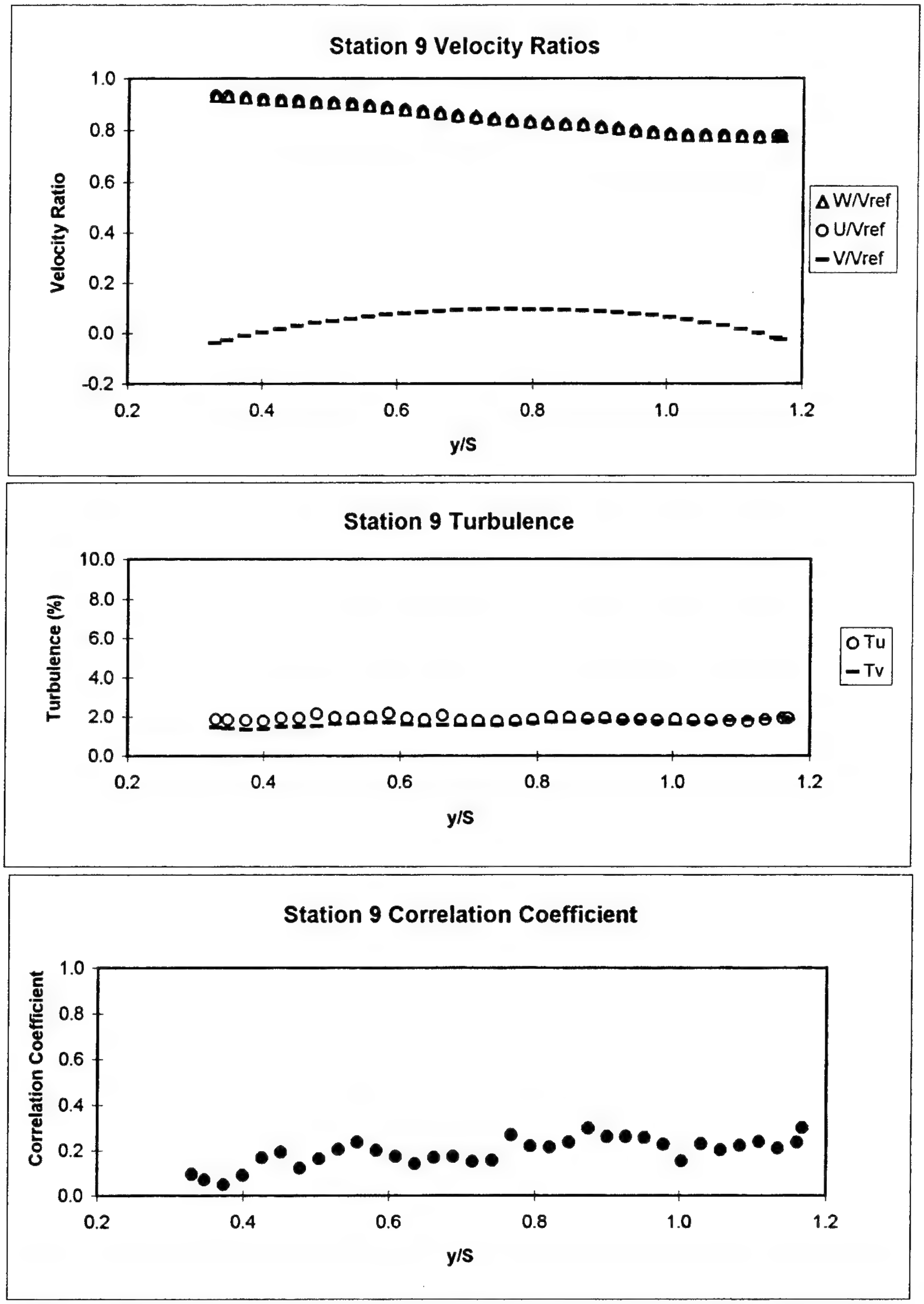
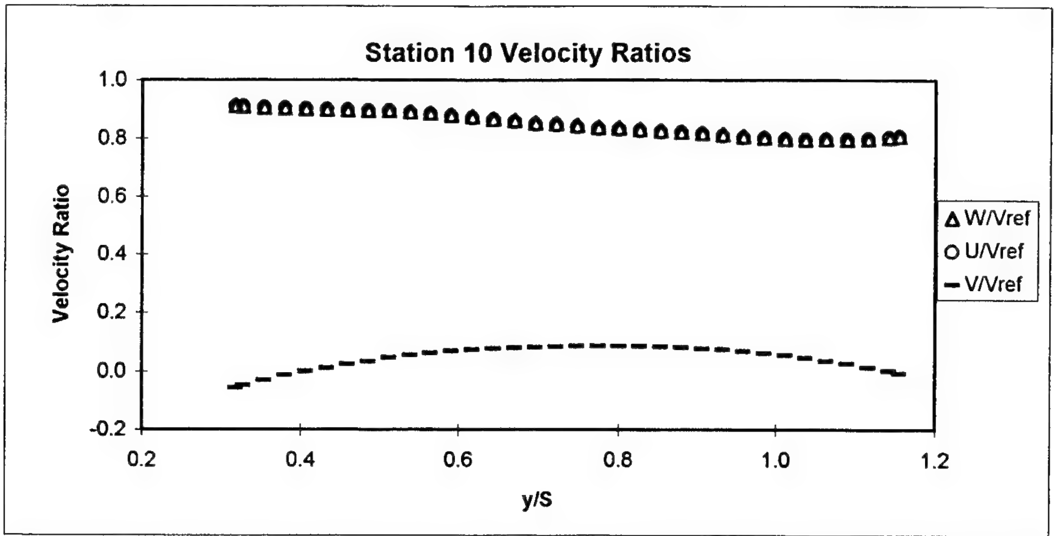
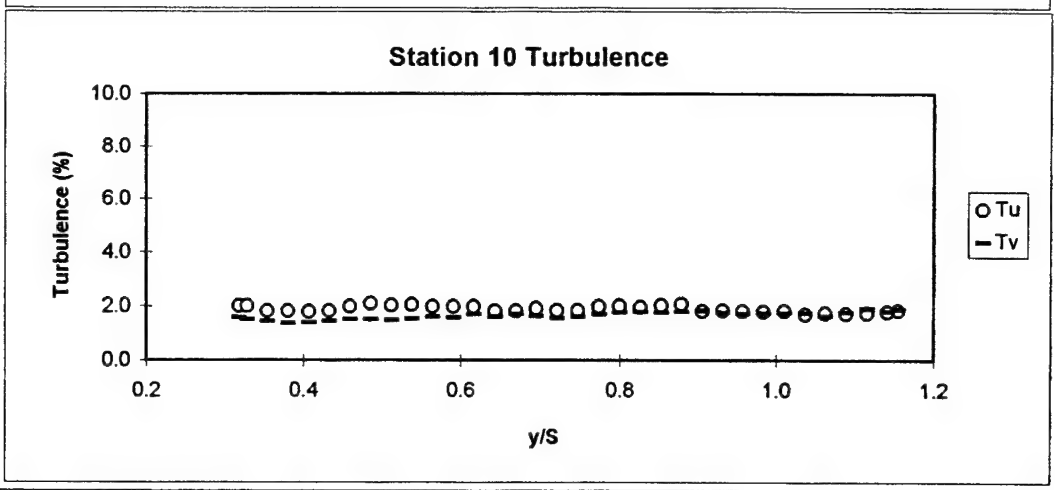


Figure 21. Station 9 Passage Survey Results.





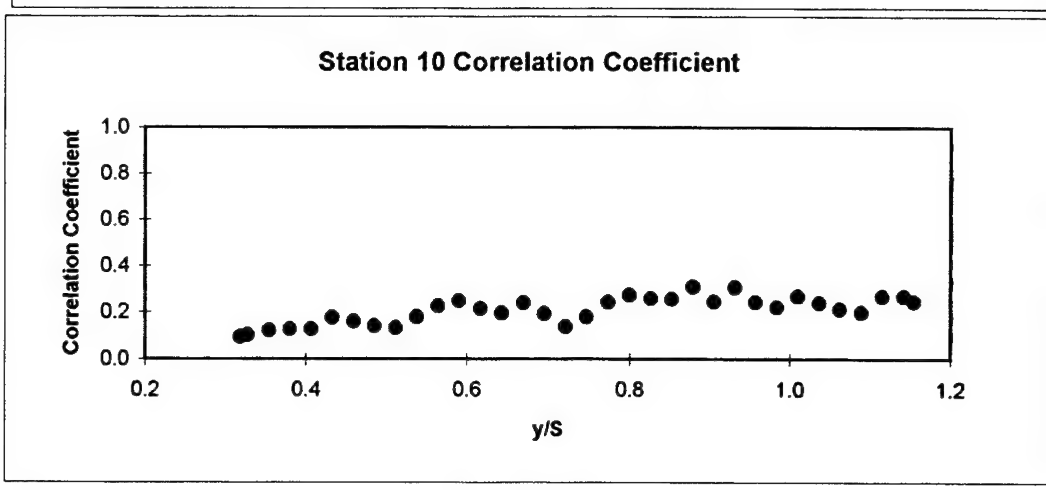


Figure 22. Station 10 Passage Survey Results.

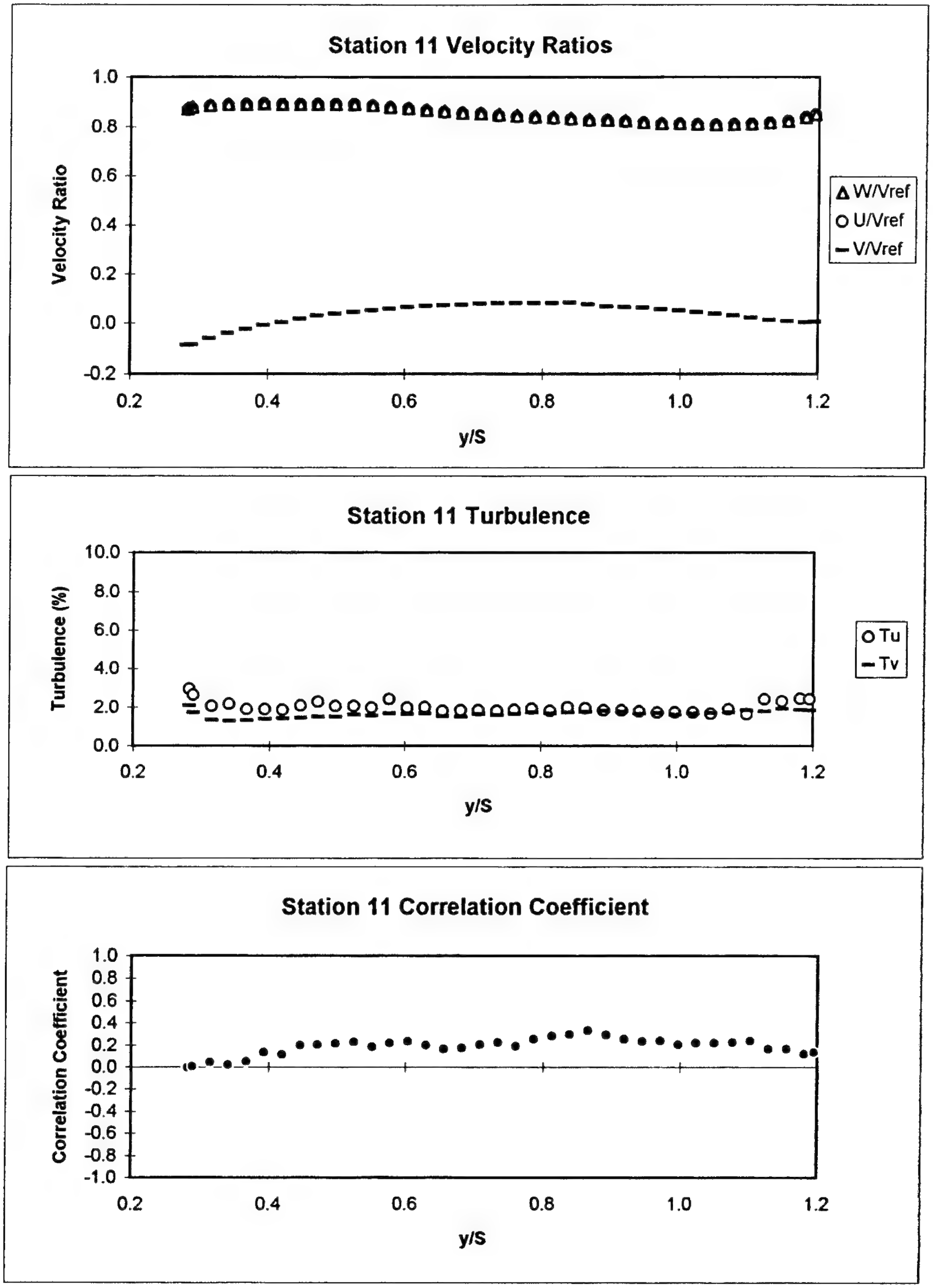


Figure 23. Station 11 Survey Results.

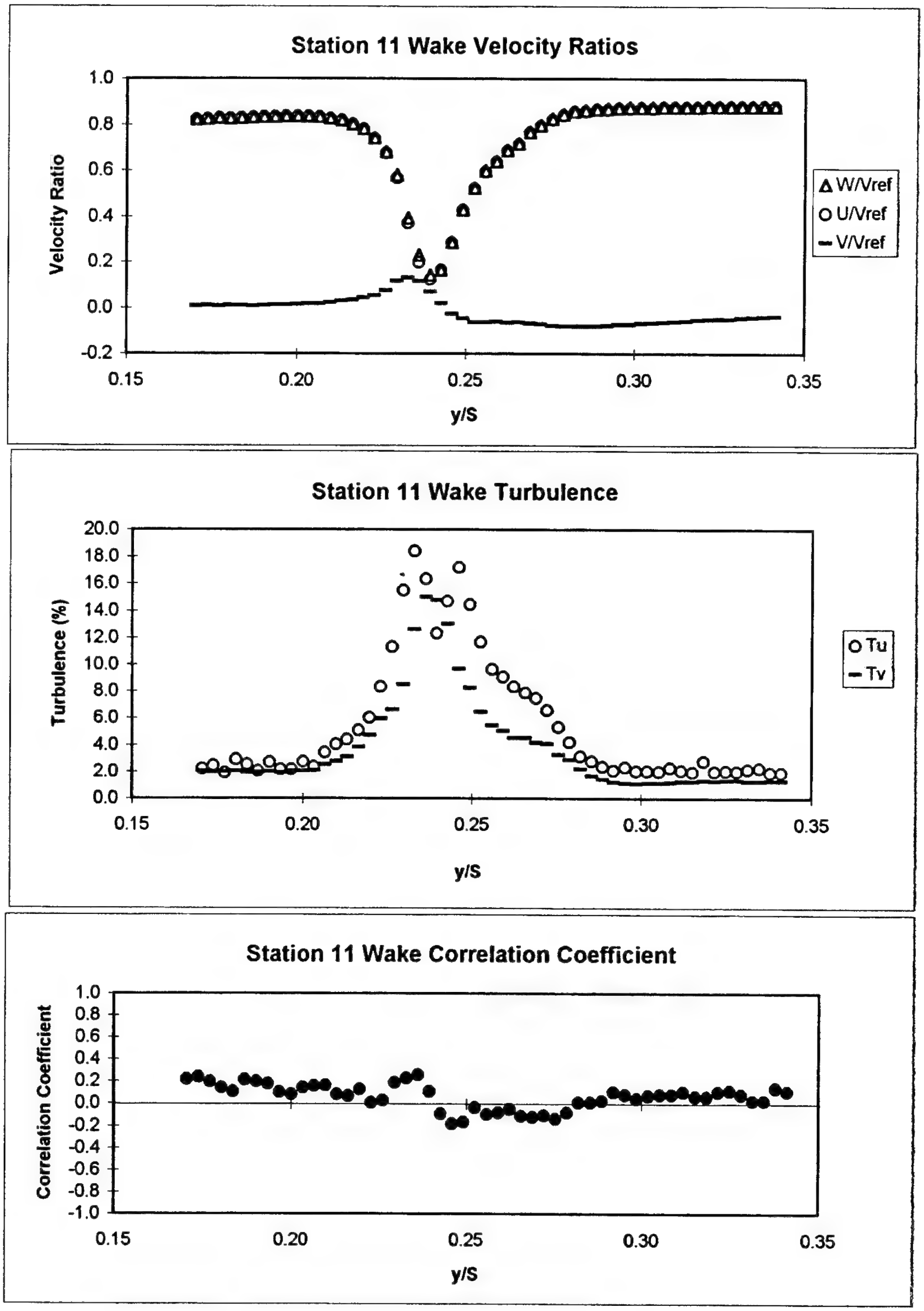


Figure 24. Station 11 Wake Survey Number 1 Results.

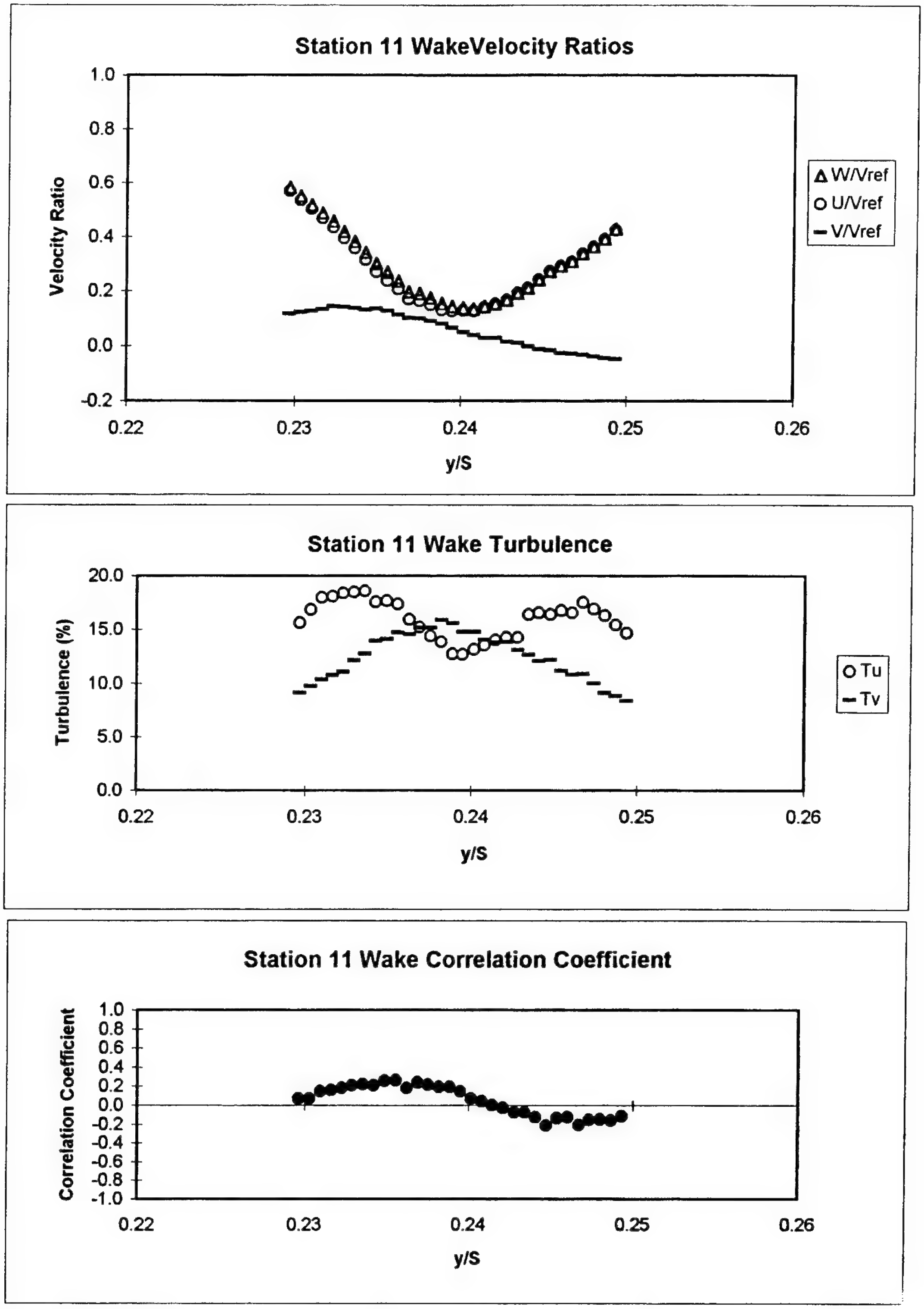


Figure 25. Station 11 Wake Survey Number 2 Results.

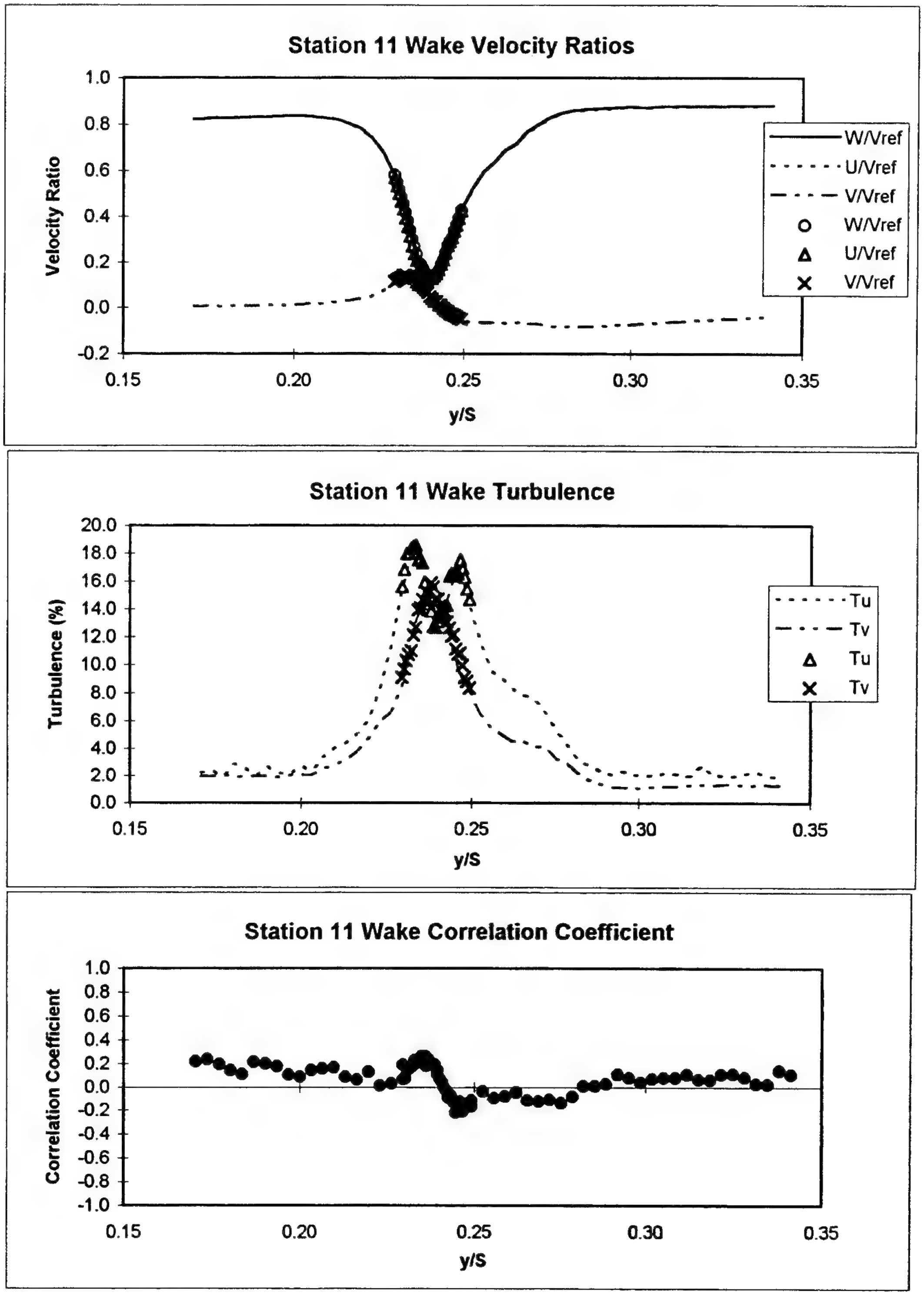


Figure 26. Station 11 Wake Surveys 1 and 2 Results.

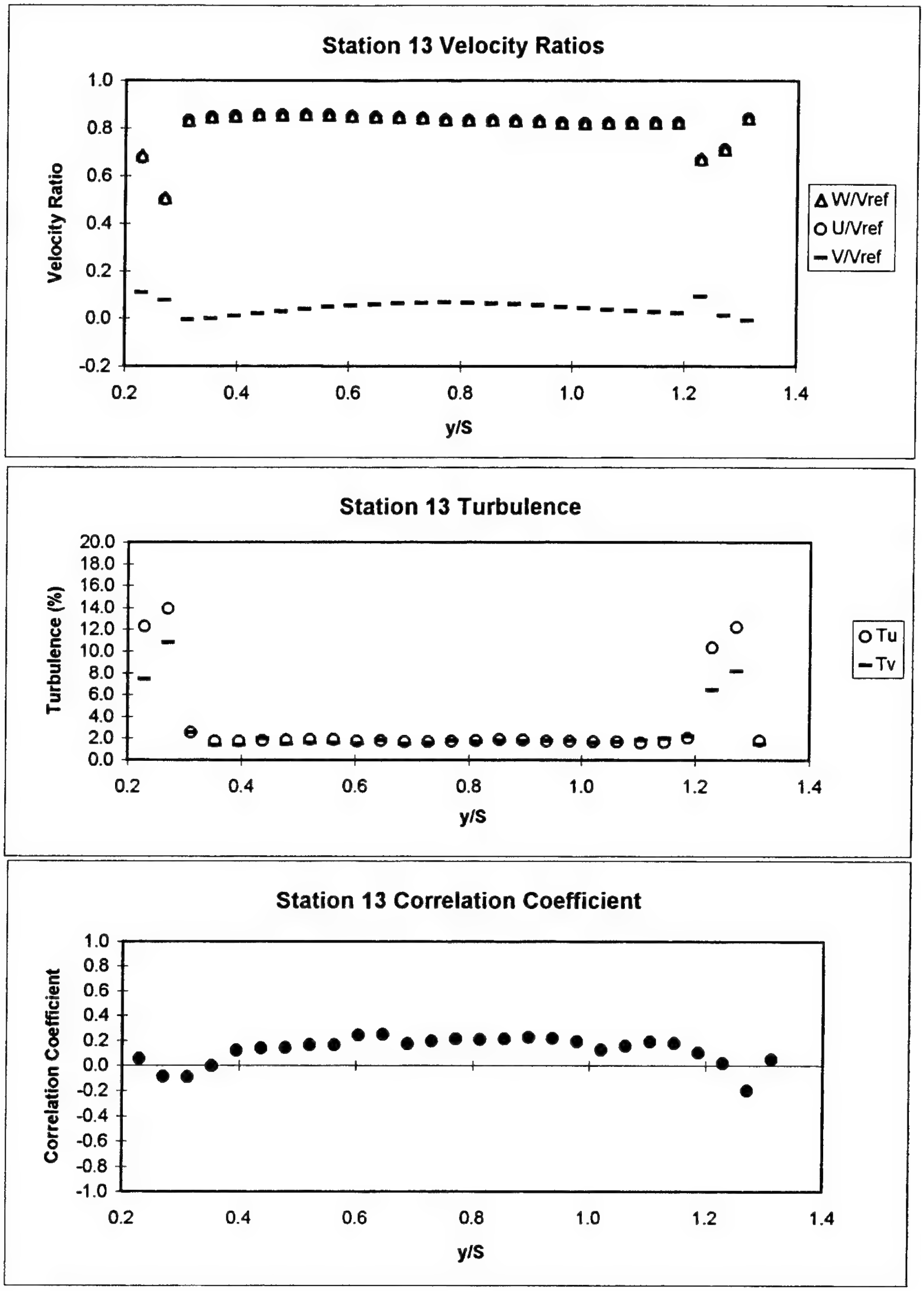


Figure 27. Station 13 Survey Results.

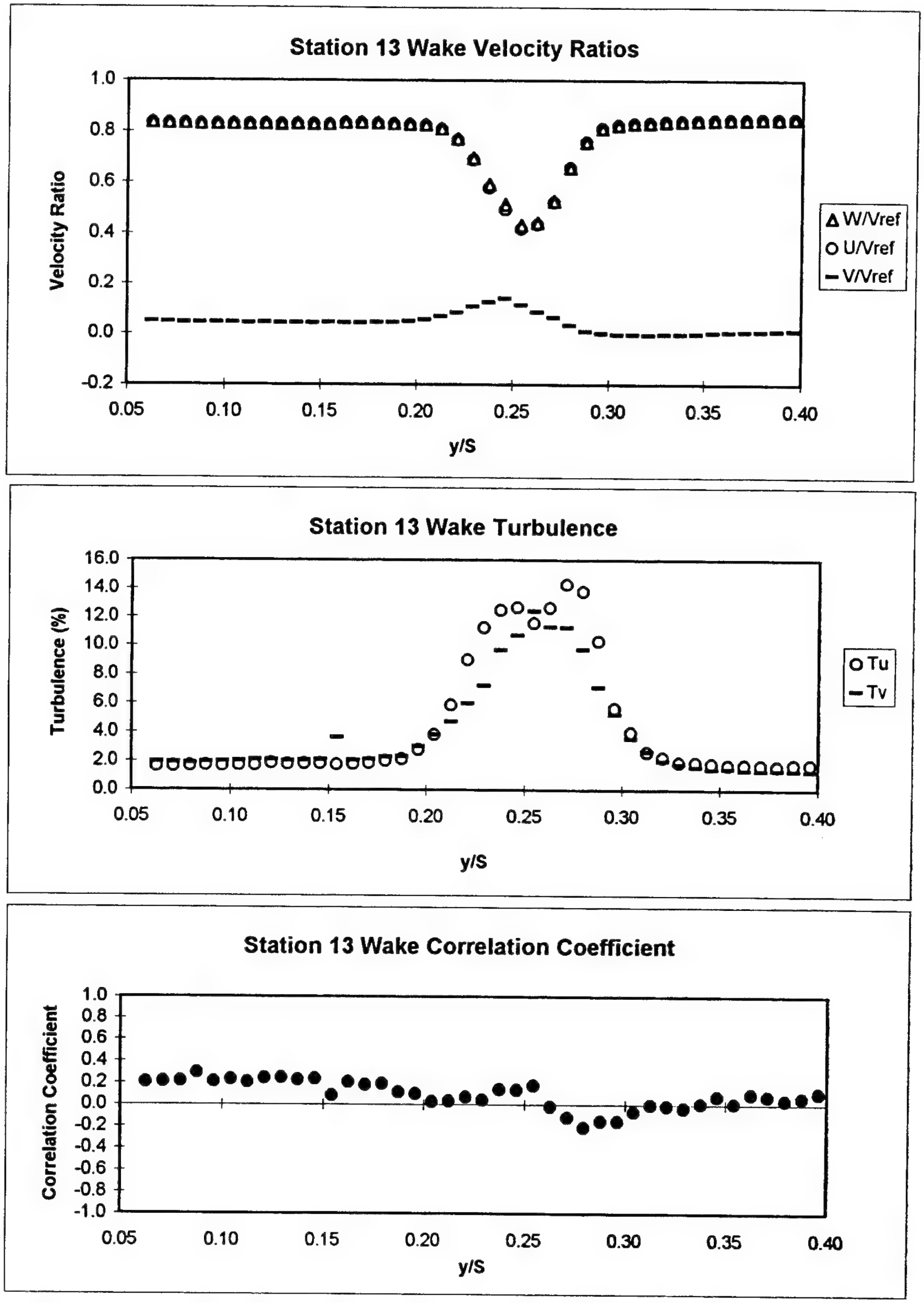
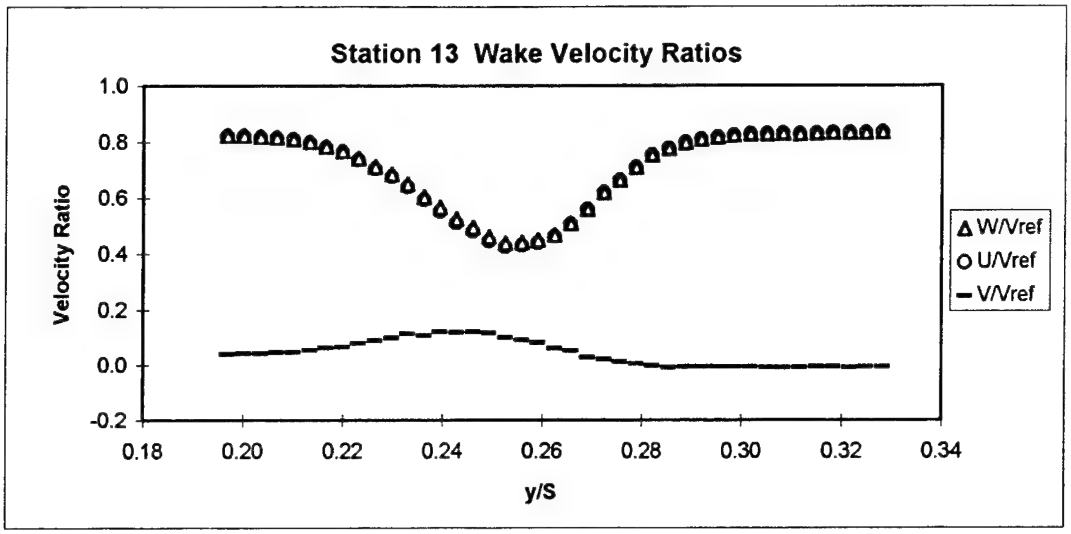
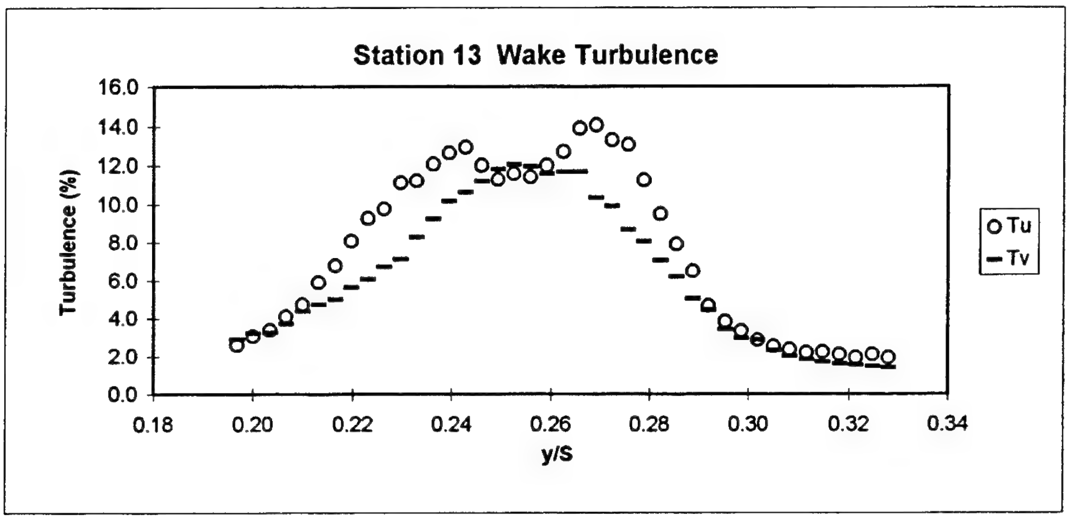


Figure 28. Station 13 Wake Survey Number 1 Results.





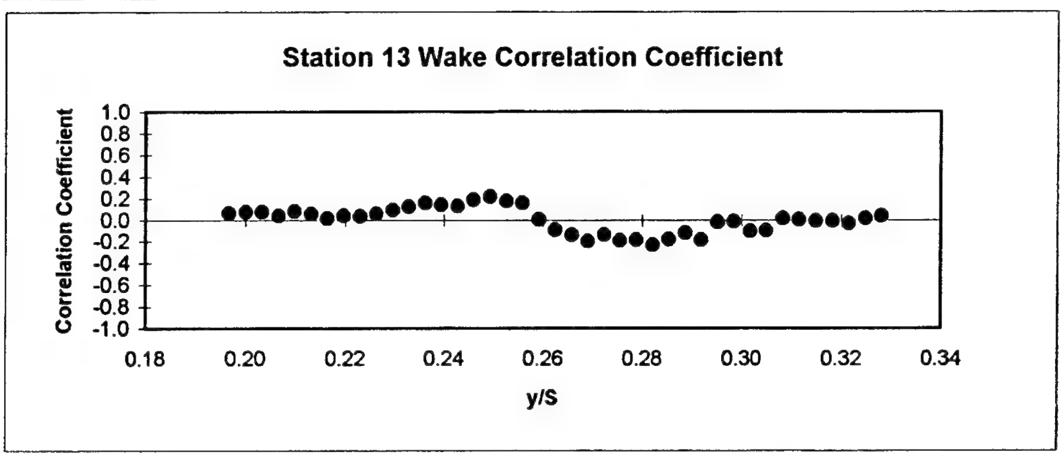


Figure 29. Station 13 Wake Survey Number 2 Results.

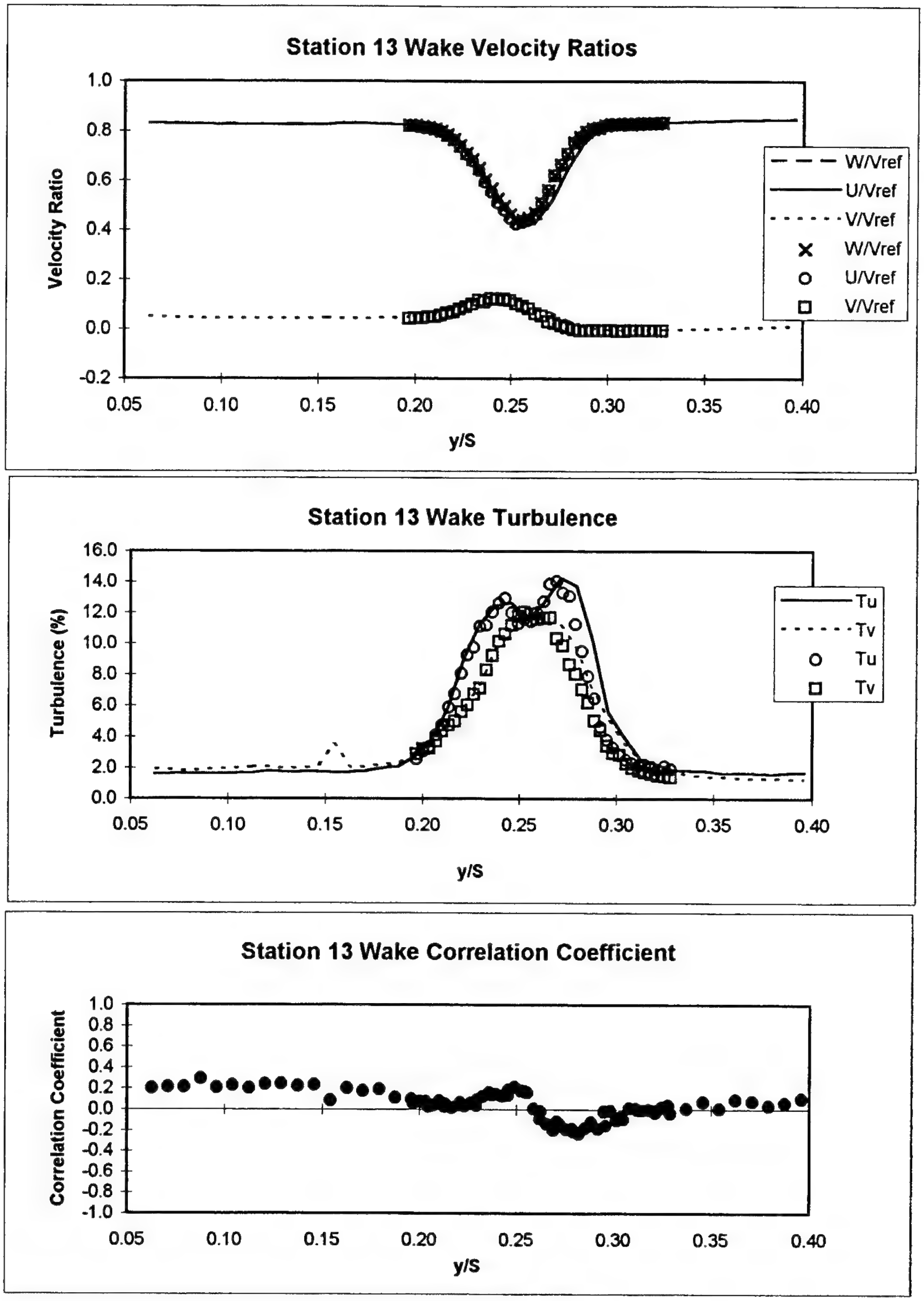


Figure 30. Station 13 Wake Surveys 1 and 2 Results.

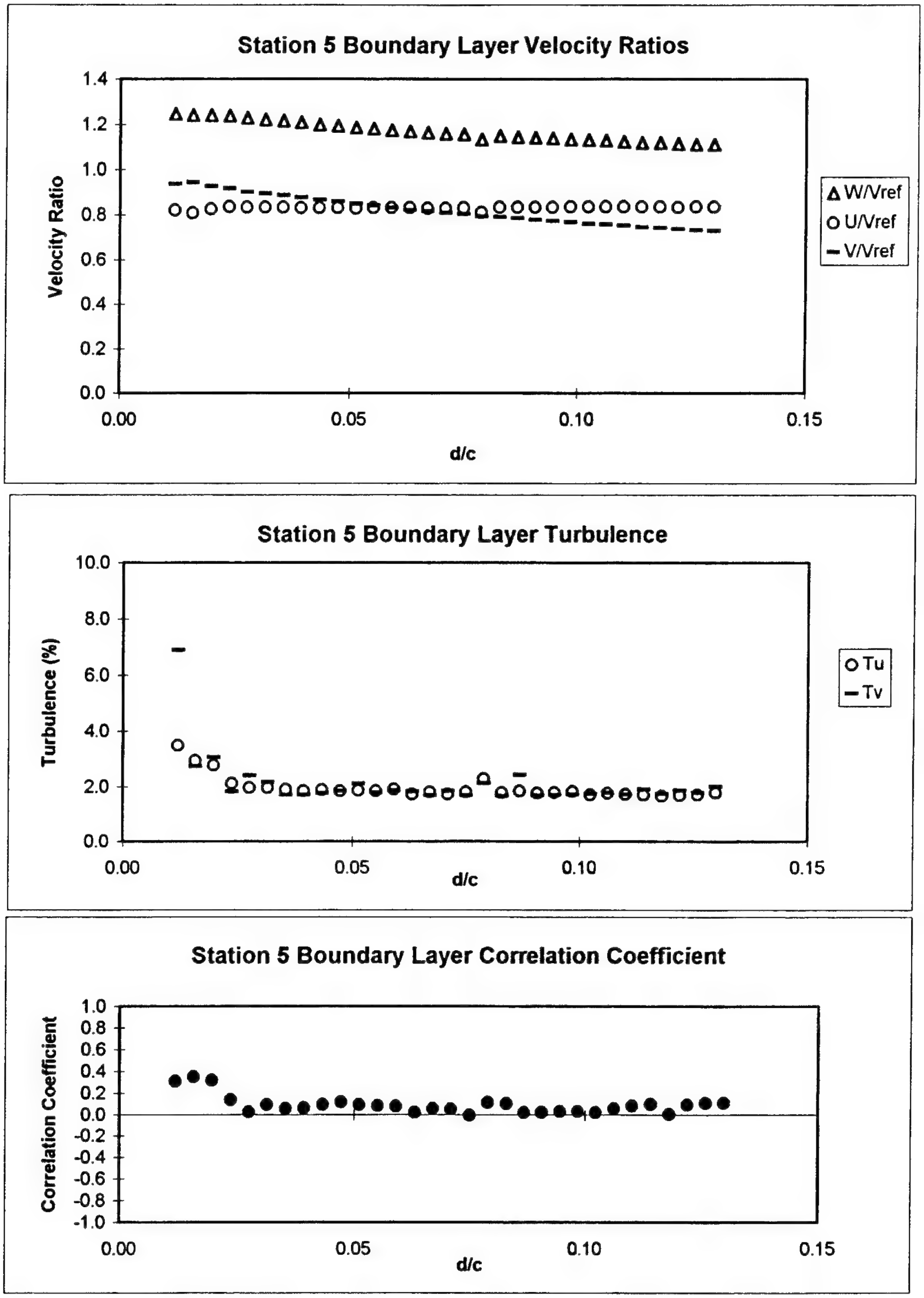


Figure 31. Station 5 Boundary Layer Survey Results.

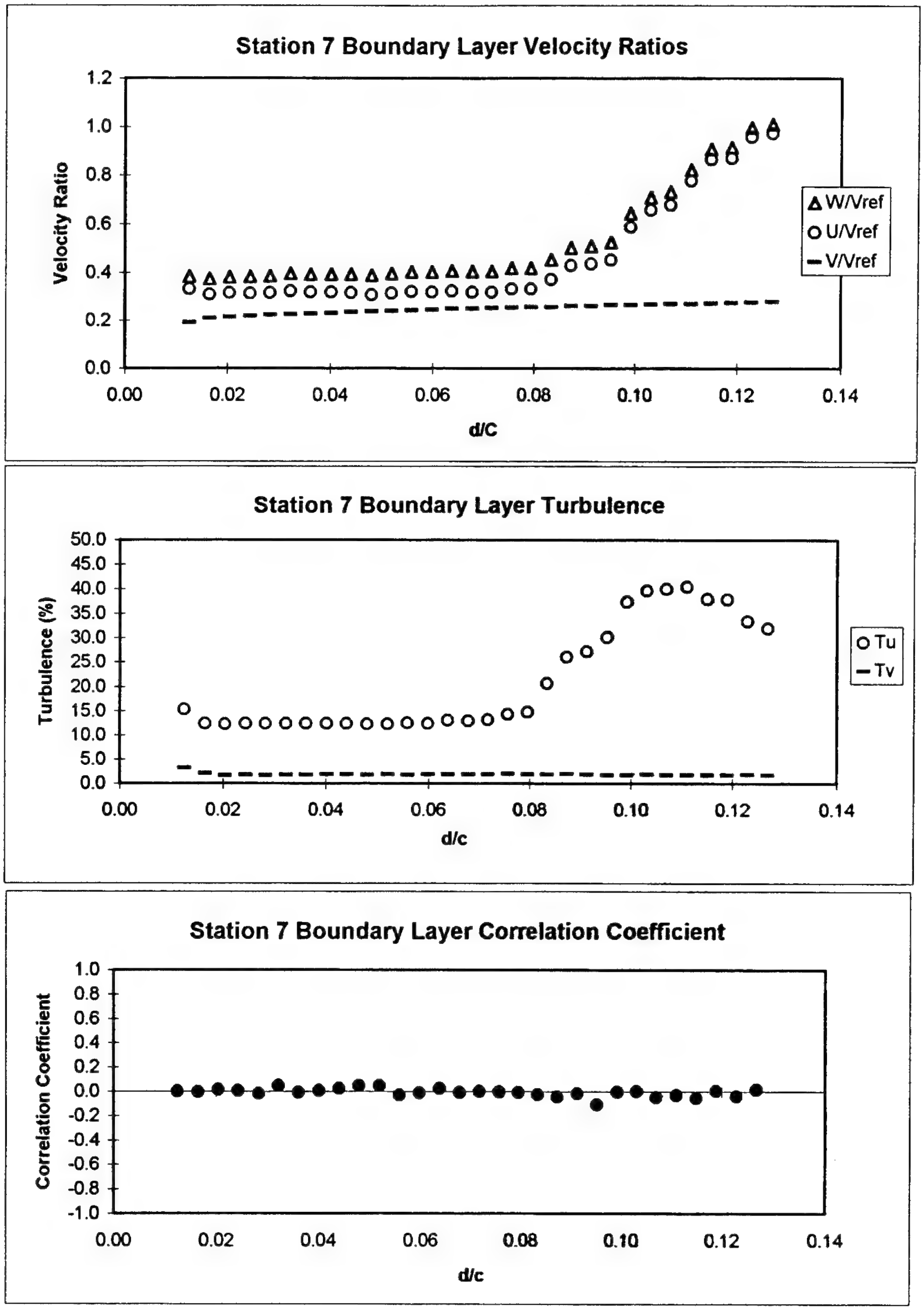


Figure 32. Station 7 Boundary Layer Survey Results.

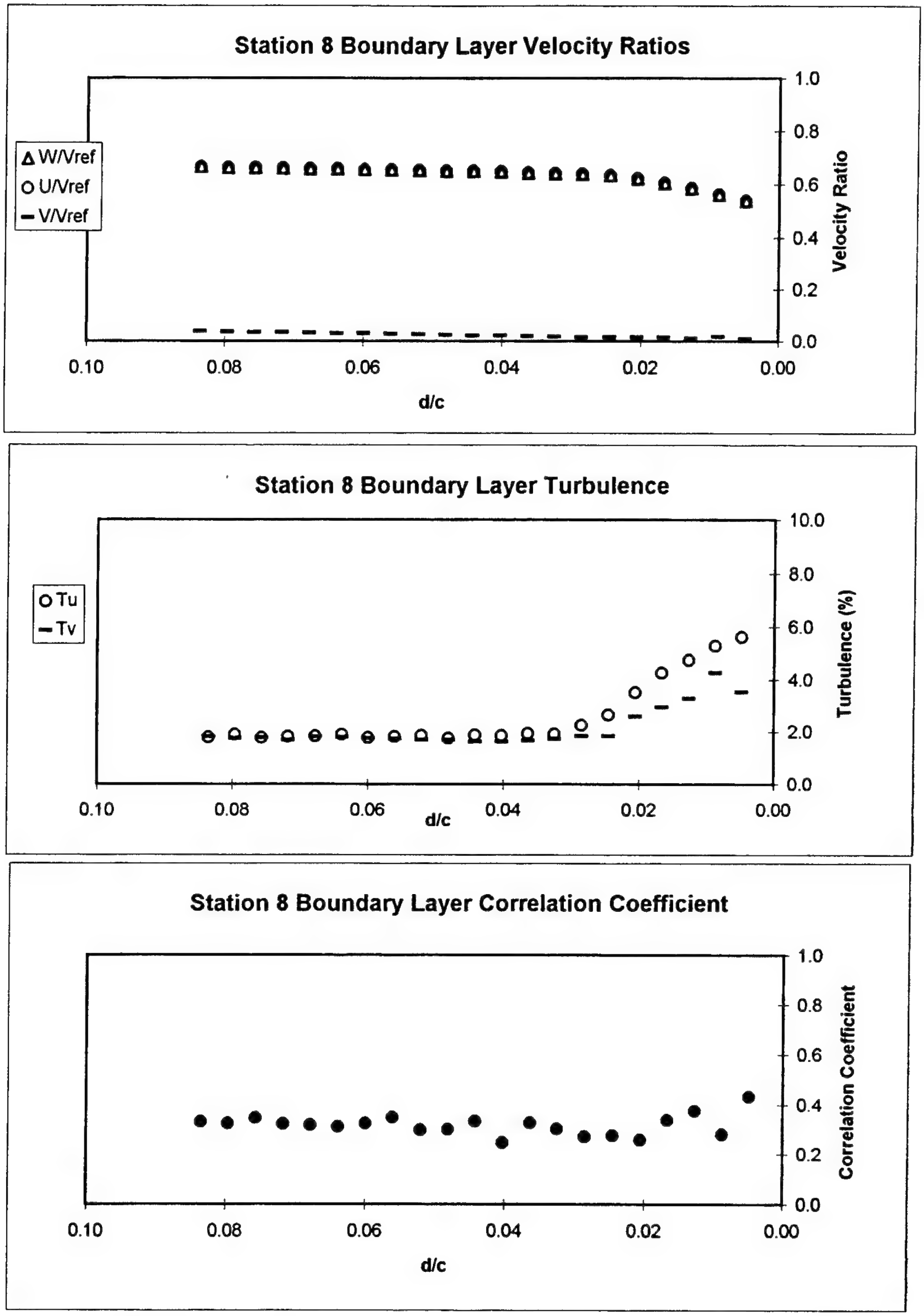


Figure 33. Station 8 Boundary Layer Survey Results.

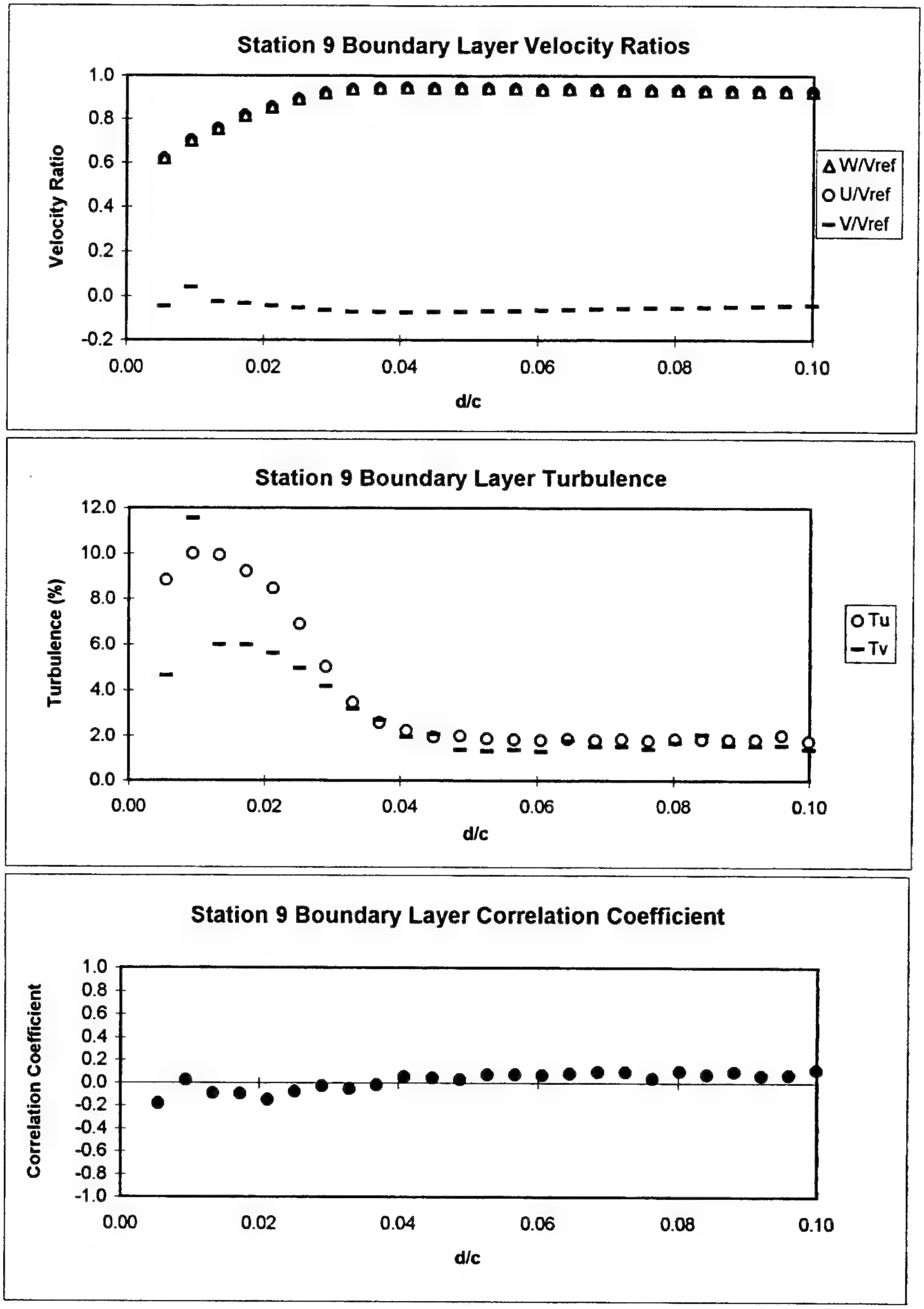


Figure 34. Station 9 Boundary Layer Survey Results.

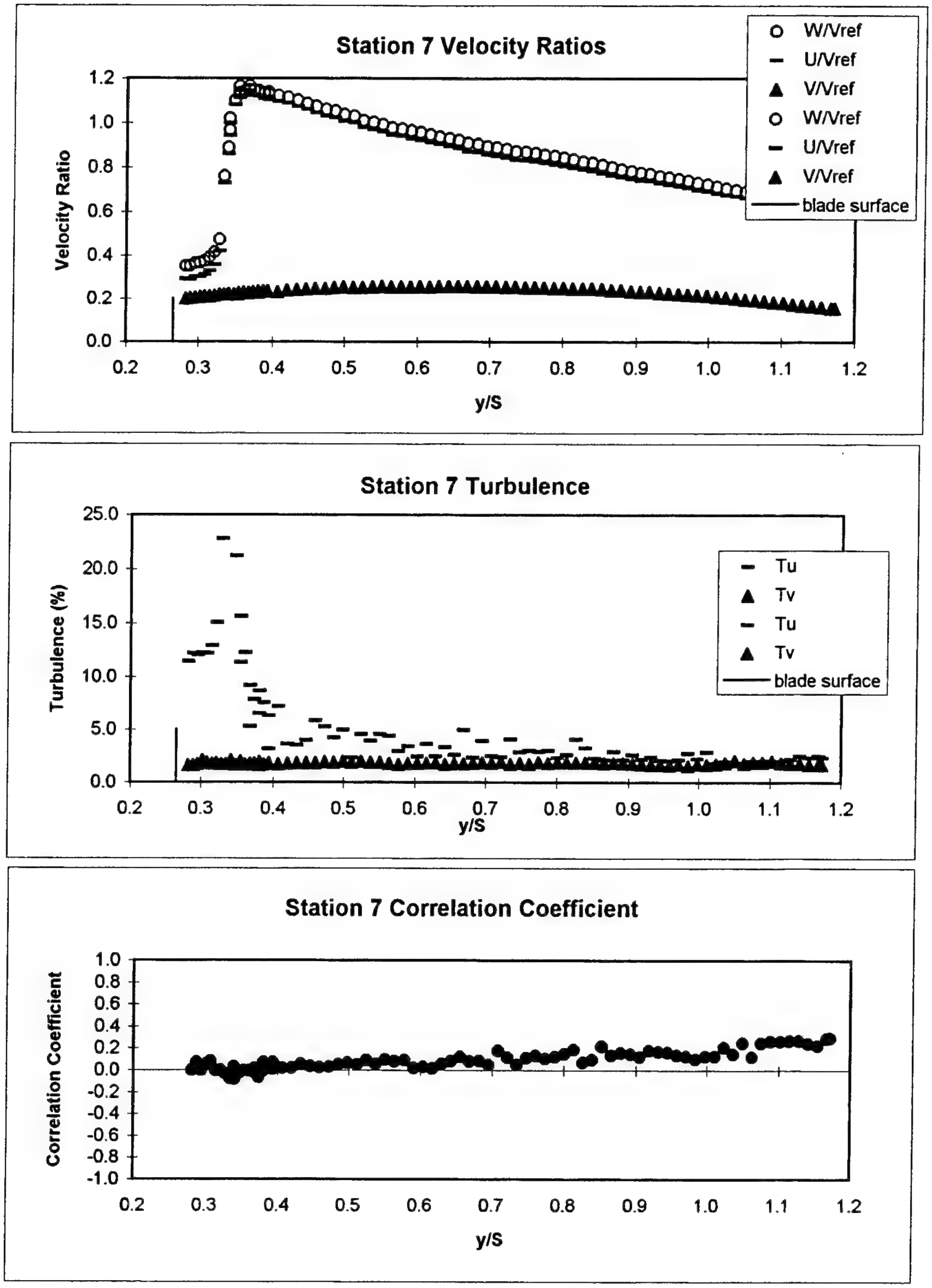


Figure 35. Station 7 Boundary Layer and Passage Survey Results.

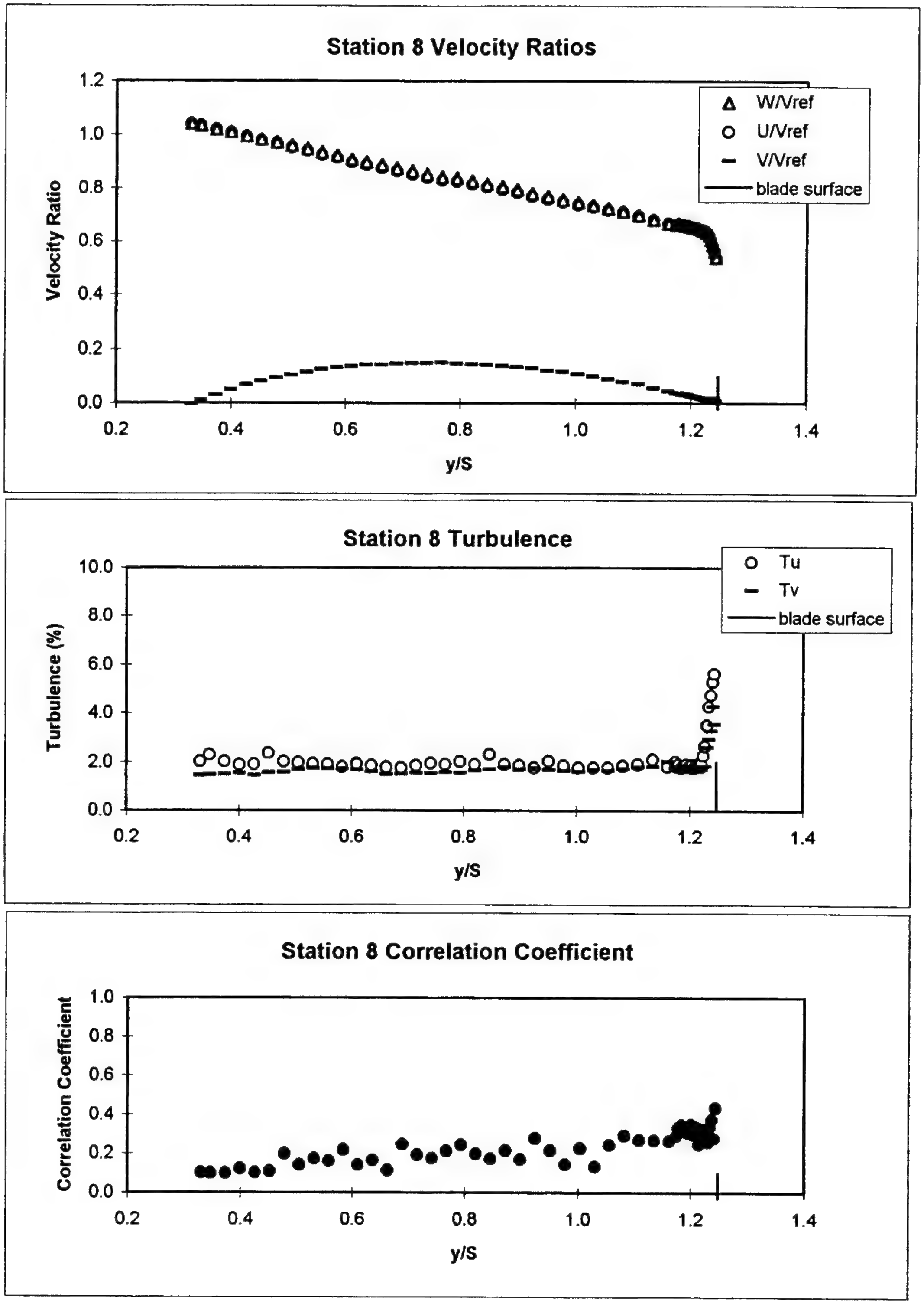


Figure 36. Station 8 Boundary Layer and Passage Survey Results.

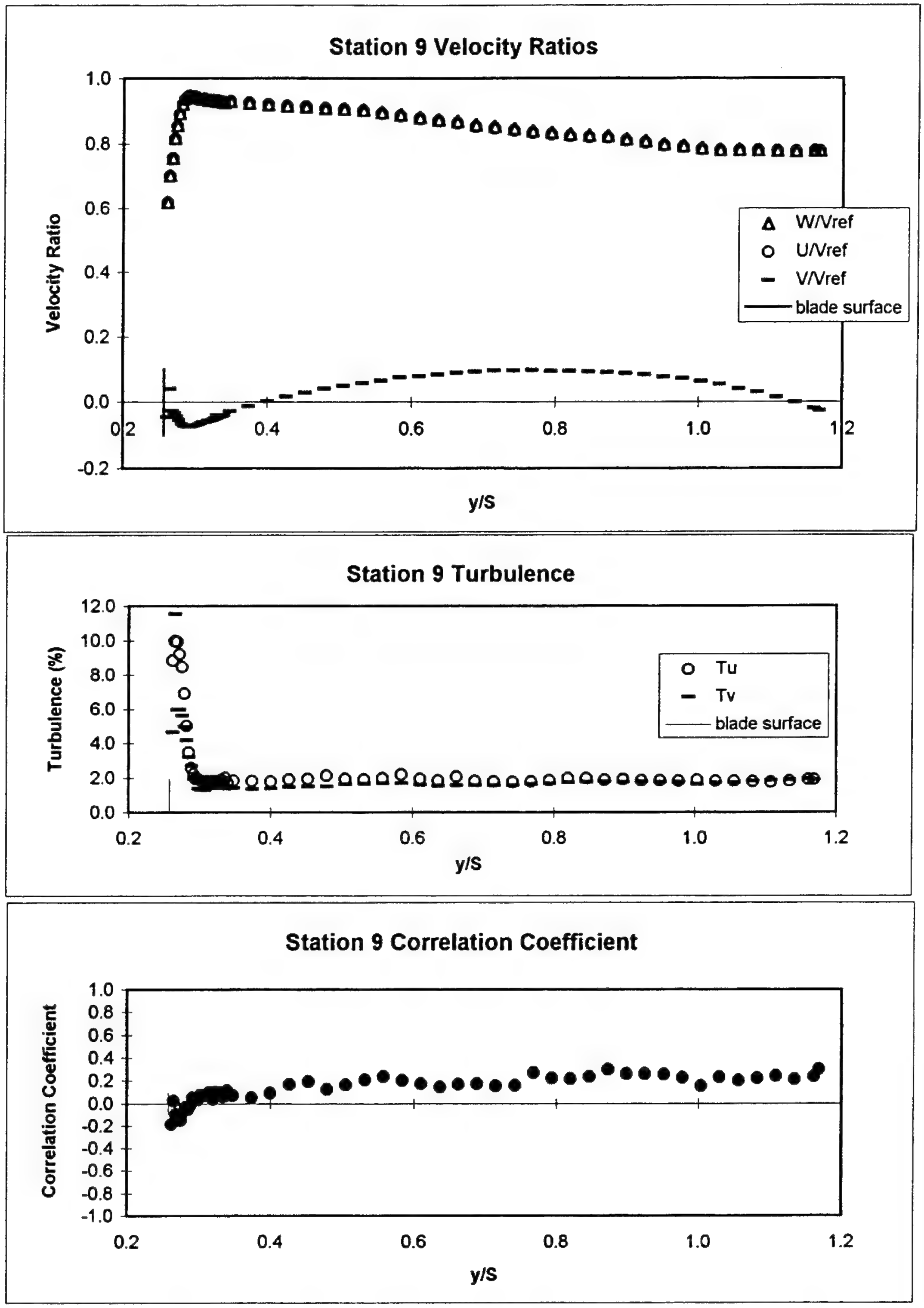


Figure 37. Station 9 Boundary Layer and Passage Survey Results.

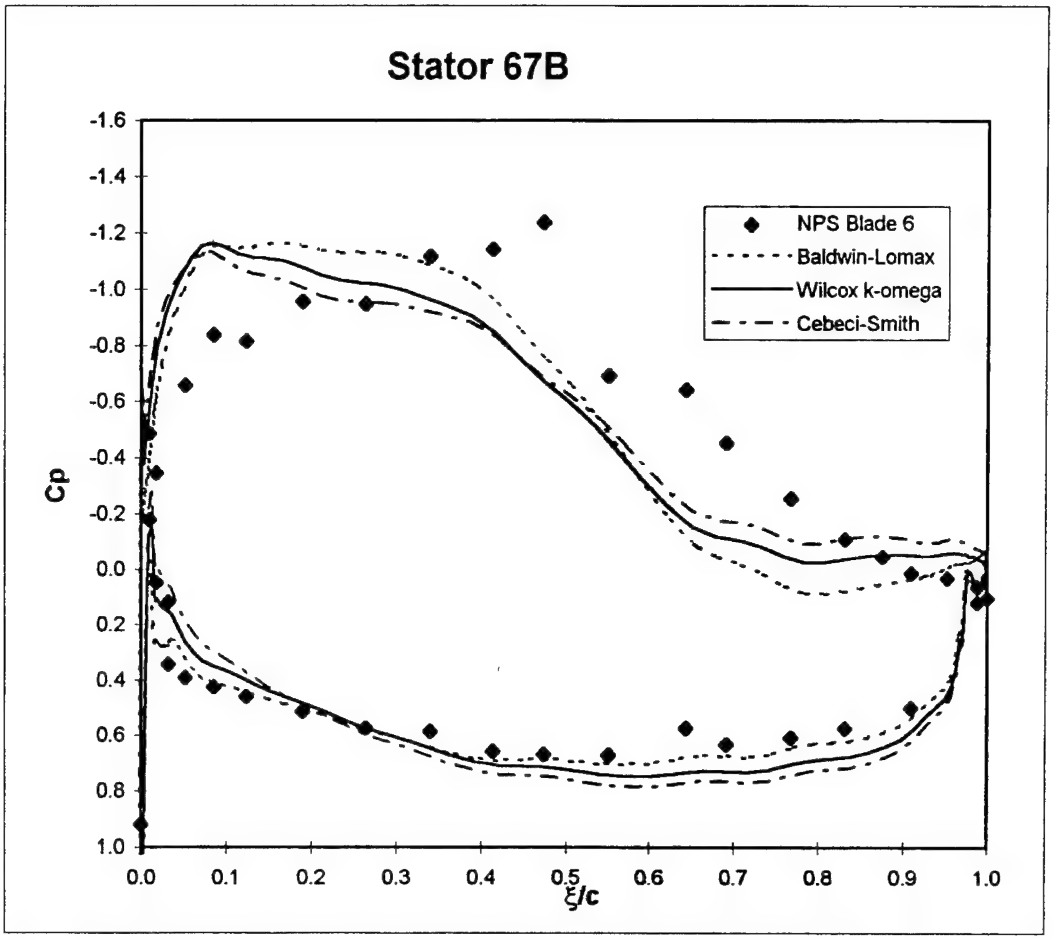


Figure 38. CFD Cp and Experimental Cp Comparison.

Model	Cebeci-Smith	Baldwin-Lomax	Wilcox k-omega
Pressure Ratio (prat)	0.9765	0.97635	0.97625

Table 3. Pressure Ratios for Turbulence Models.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Compressor Stator 67B cascade blading was successfully installed and experimentally tested at design conditions in the NPS Low-Speed Cascade Wind Tunnel. The experiments were conducted at a design inlet-flow angle of 36.3 degrees, a Mach number of 0.22 and a Reynolds number based on chord of 640,000.

Experimental blade surface pressure measurements were obtained using water manometers and an HP automated data acquisition system. The resulting Cp plots showed that the flow on the suction side rapidly accelerated from the leading edge, more gradually accelerated until midspan, and then gradually decelerated to the trailing edge. Fluctuations in pressure on the suction side of the blades observed during the experiments suggested unsteady flow or separation had occurred on the blade, and this was later confirmed with LDV passage and boundary layer surveys.

Experimental measurements yielded a loss of 0.029. These results compared well to NASA LeRC loss values of 0.030 [Ref. 1]. However, the NASA results were from tests of the entire stage, so the comparison is not totally valid.

The LDV results characterized the flow in the inlet, in the blade passage, in the boundary layers and at the exit of the test section at design conditions. Inlet surveys measured the upstream influence of the blades. Passage surveys showed a smooth acceleration up to a separation point in the vicinity of Station 7 on the suction side of the blade, and then a smooth deceleration and reattachment of the flow. With the presence of separation, although the blade produced a useful force, the controlled diffusion design goal of preventing separation at design incidence was not achieved. Boundary-layer surveys were successfully performed at three suction-side stations, and one pressure-side station. The boundary-layer surveys defined the growth of the boundary layer throughout the passage. Wake surveys showed the influence of mixing in the wake.

CFD predictions of the blade surface pressure coefficients using RVCQ3D Version 300 did not correlate well with the experimental results. Three different turbulence models were used, with similar results.

B. RECOMMENDATIONS

More extensive boundary-layer surveys and analysis should be performed at design incidence to determine more exactly the regions of separation and reverse flow. Laser rotation, in addition to laser pitch and yaw, could allow the LDV probe volume to be positioned closer to the blade surface at the measurement stations. Flow visualization using a laser sheet should be performed to help determine the separation location, and to determine the extent of the separation region.

The five-hole probe data acquisition system should be improved by updating the survey equipment, and controlling software. A computer-controlled automatic-traverse mechanism for the five-hole probe, and an automated yaw system to align the five-hole probe with the flow, would permit surveys to be accomplished more rapidly. An update of the HP BASIC software to include self-adjusting time pauses to allow settling of pressure data prior to recording, point-by-point data recording in case of system failure, and an option to use Prandtl probe pressures for reference should be implemented immediately. The option of using software based on "LabVIEW" to control the system should be investigated. Finally, the five-hole probe calibration coefficients should be verified before further probe surveys are conducted.

Additional analysis with RCVQ3D should be performed to try to reproduce the experimental results. Different grid sizes and number of iterations should be investigated. Also, the incidence angle should be varied in an attempt to match the inlet flow conditions. Loss calculations should be included in the CFD analysis. Experimentation with a full three dimensional code might provide better results.

When the flow at the design incidence angle is initially characterized, positive off-design incidence angles should be set to determine immediately the available range of incidence and the on-set of stall. This will allow the future test plan to be determined most optimally.

APPENDIX A. FIVE-HOLE PROBE EQUATIONS

Dimensionless velocity coefficient: $$\beta = \frac{p_1 - p_{23}}{p_1}$$

Average yaw pressure: $$p_{23} = \frac{p_2 + p_3}{2}$$

Pitch angle coefficient: $$\gamma_{5\text{-hole}} = \frac{p_4 - p_5}{p_1 - p_{23}}$$

Dimensionless velocity coefficients [Ref. 8] C_{ij}:

	C_{i1}	C_{i2}	C_{i3}	C_{i4}	C_{i5}
C_{1j}	0.015926	4.932133	-153.66876	3137.9614	-24299.005
C_{2j}	-0.003563	0.699505	-62.977261	2068.3721	-20872.148
C_{3j}	0.080098	-24.844173	1980.4954	1980.4954	541835.5

Dimensionless velocity polynomial:

$$\begin{aligned} X = &\left\{C_{11} + C_{12}\cdot\beta + C_{13}\cdot\beta^2 + C_{14}\cdot\beta^3 + C_{15}\cdot\beta^4\right\} \\ &+\left\{C_{21} + C_{22}\cdot\beta + C_{23}\cdot\beta^2 + C_{24}\cdot\beta^3 + C_{25}\cdot\beta^4\right\}\cdot\gamma_{5\text{-hole}} \\ &+\left\{C_{31} + C_{32}\cdot\beta + C_{33}\cdot\beta^2 + C_{34}\cdot\beta^3 + C_{35}\cdot\beta^4\right\}\cdot\gamma_{5\text{-hole}}^2 \end{aligned}$$

Reference dimensionless velocity: $$X_{ref} = \sqrt{1 - \left(\frac{P_s}{P_t}\right)^{\left(\frac{\gamma-1}{\gamma}\right)}}$$

Reference flow function: $$K = \frac{X}{X_{ref}}\left[\frac{1 - X^2}{1 - X_{ref}^2}\right]^{\frac{1}{\gamma-1}} \cos(\beta_{5\text{-hole}})$$

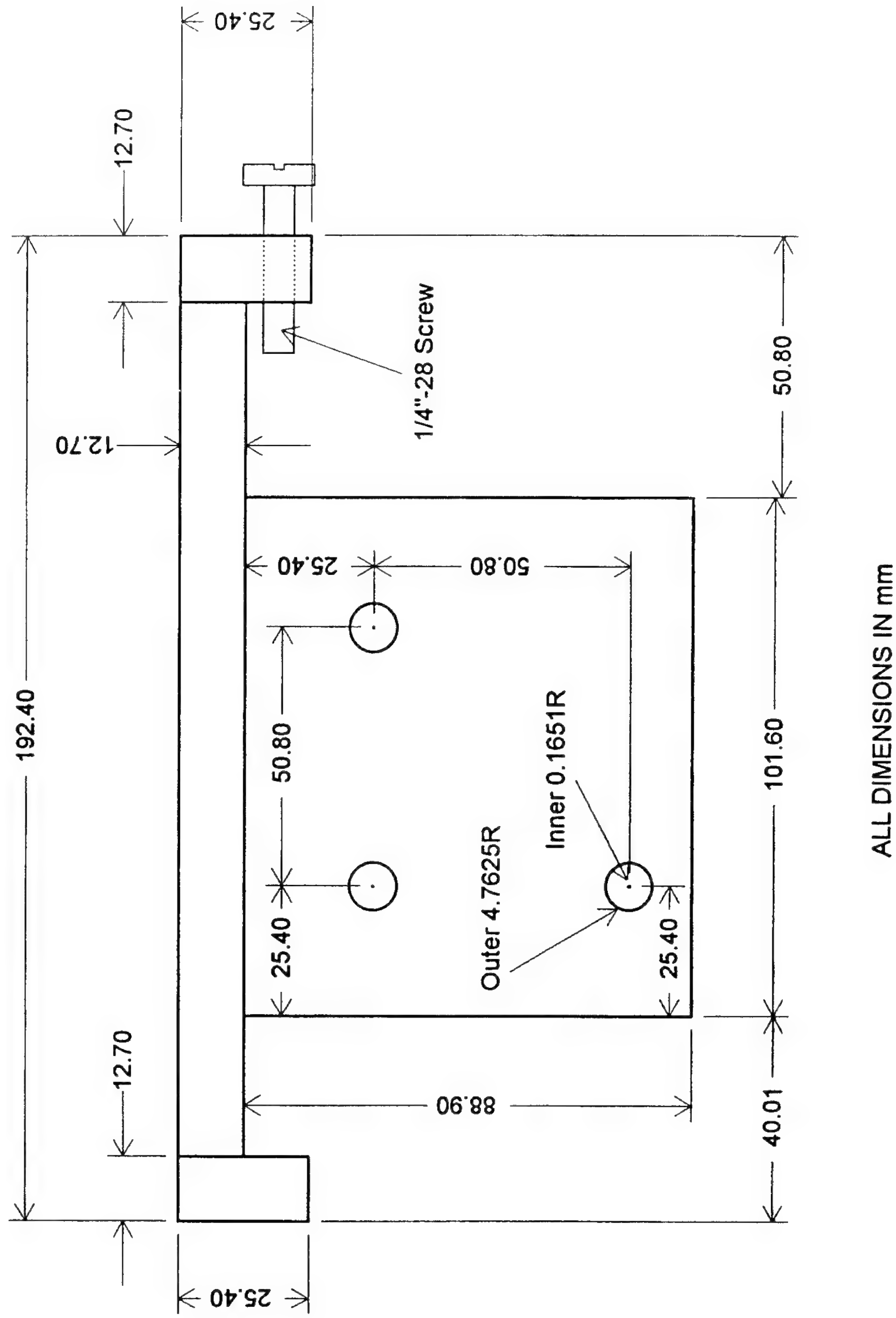
Axial-Velocity-Density Ratio: $$AVDR = \frac{\int_0^S K_{ds}\,dx}{\int_0^S K_{us}\,dx}$$

Dimensionless total pressure: $$C_{pt} = \frac{P_1}{P_t}$$

Dimensionless static pressure: $$C_{ps} = \frac{P_{23}}{P_t}$$

Loss coefficient: $$\omega = \frac{\int_0^S C_{ptus} K_{us} dx - \frac{1}{AVDR} \int_0^S C_{ptds} K_{ds} dx}{\int_0^S C_{ptus} K_{us} dx - \int_0^S C_{psus} K_{us} dx}$$

APPENDIX B. DIMENSIONS OF THE LASER ALIGNMENT TOOL



APPENDIX C. LDV SUMMARY AND REDUCED DATA

LDV Summary										
Survey Number	Station	Date taken	Vref (m/s)	Spacing (mm)	Number of Points	Tpl (F)	Ppl (" H2O)	Patm (psi)	Yaw (deg.)	Pitch (deg.)
1	1a	April 1	75.62	6.35	41	70	12.00	14.72		
2	1b	April 18	75.64	6.35	27	73	11.90	14.71		
3	2a	May 7	75.27	2.54	81	68	11.90	14.60		
4	2b	May 26	75.35	5.08	41	68	11.95	14.71	0	5 up
5	3a	May 7	75.49	2	72	69	11.95	14.68		
6	3b	May 26	75.57	2.54	41	69	12.00	14.71	0	5 up
7	4	May 7	75.72	2	67	70	12.00	14.68		
8	5	May 9	75.78	2	63	69	12.10	14.75		
9	5 BL	June 3	75.44	0.5	31	69	11.95	14.70	5 left	0
10	6a	May 9	75.52	2	65	70	12.00	14.70		
11	6b	May 20	75.36	2	65	70	11.90	14.70		
12	7a	May 16	75.53	2	66	71	11.90	14.66		
13	7b	Sep 1	75.64	1	19	77	11.80	14.66	4 left	0
14	7 BL	Sep 1	75.73	0.5	30	76	11.85	14.66	4 left	0
15	7b BL	Sep 1	75.89	0.25	50	72	12.00	14.67	4 left	0
16	8	May 6	76.01	4	34	69	12.10	14.65		
17	8 BL	May 20	76.46	0.5	21	72	12.20	14.69	4.5 right	1 down
18	9	May 6	76.01	4	34	69	12.10	14.65		
19	9 BL	July 8	76.27	0.5	25	78	12.00	14.69	4 left	2 down
20	10	May 6	76.01	4	34	69	12.10	14.65		
21	11a	May 6	75.60	4	37	68	12.00	14.67		
22	11b	May 20	75.19	0.5	53	72	11.80	14.70	0	5 down
23	11c	May 20	75.66	0.1	31	72	12.20	14.69	0	5 down
24	12a	May 2	75.33	6.35	27	70	11.90	14.71		
25	12b	May 2	75.33	0.5	61	70	11.90	14.71		
26	13a	May 2	75.95	6.35	27	70	12.10	14.71		
27	13b	May 2	75.33	1.27	41	70	11.90	14.71		
28	13c	May 2	75.33	0.5	41	70	11.90	14.71		

Survey Number 1									
Station 1									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
-36.574	-50.800	-0.333	0.993	0.813	0.570	3.492	1.992	0.073	0.018
-36.574	-44.450	-0.292	0.987	0.806	0.570	2.933	1.870	0.204	0.065
-36.576	-38.100	-0.250	0.985	0.801	0.573	2.771	1.741	0.157	0.057
-36.578	-31.750	-0.208	0.981	0.796	0.573	2.851	1.906	0.204	0.066
-36.576	-25.400	-0.167	0.973	0.784	0.575	3.228	1.861	0.264	0.077
-36.574	-19.050	-0.125	0.970	0.778	0.579	2.637	1.802	0.178	0.065
-36.578	-12.700	-0.083	0.972	0.774	0.588	3.038	1.787	0.189	0.061
-36.576	-6.350	-0.042	0.978	0.774	0.598	2.815	1.880	0.107	0.035
-36.576	0.002	0.000	0.984	0.774	0.607	3.040	1.826	0.104	0.033
-36.576	6.350	0.042	0.994	0.782	0.613	2.080	1.788	0.144	0.068
-36.576	12.700	0.083	1.005	0.791	0.620	2.851	1.770	0.208	0.072
-36.576	19.050	0.125	1.018	0.804	0.625	2.432	1.897	0.165	0.063
-36.576	25.400	0.167	1.021	0.809	0.623	2.636	1.959	0.253	0.086
-36.576	31.750	0.208	1.022	0.814	0.618	2.938	1.914	0.258	0.080
-36.576	38.100	0.250	1.025	0.820	0.614	2.781	1.945	0.122	0.040
-36.576	44.450	0.292	1.026	0.827	0.608	2.437	1.750	0.126	0.052
-36.576	50.800	0.333	1.026	0.831	0.602	2.286	1.802	0.112	0.047
-36.576	57.150	0.375	1.022	0.832	0.593	2.165	2.031	0.171	0.068
-36.576	63.500	0.417	1.020	0.832	0.589	2.990	1.878	0.287	0.089
-36.574	69.850	0.458	1.020	0.837	0.583	2.229	1.972	0.267	0.106
-36.576	76.200	0.500	1.013	0.833	0.577	2.560	1.950	0.188	0.066
-36.576	82.550	0.542	1.002	0.825	0.569	2.587	1.927	0.111	0.039
-36.576	88.900	0.583	0.996	0.819	0.566	2.781	1.803	0.103	0.036
-36.576	95.250	0.625	0.988	0.811	0.564	3.179	1.763	0.184	0.057
-36.576	101.600	0.667	0.987	0.809	0.566	2.955	1.767	0.142	0.048
-36.574	107.950	0.708	0.981	0.802	0.565	3.767	1.799	0.257	0.066
-36.574	114.302	0.750	0.976	0.793	0.569	3.301	1.829	0.279	0.081
-36.574	120.650	0.792	0.973	0.788	0.571	2.926	1.873	0.198	0.063
-36.576	127.000	0.833	0.972	0.782	0.577	3.360	1.778	0.248	0.073
-36.574	133.350	0.875	0.972	0.779	0.581	3.085	1.947	0.221	0.064
-36.576	139.700	0.917	0.976	0.778	0.589	2.666	1.896	0.071	0.025
-36.576	146.050	0.958	0.980	0.777	0.597	3.021	1.749	0.111	0.037
-36.576	152.400	1.000	0.988	0.779	0.608	3.077	1.869	0.051	0.015
-36.576	158.750	1.042	0.995	0.786	0.610	3.105	1.840	0.157	0.048
-36.576	165.100	1.083	1.007	0.796	0.617	2.816	1.888	0.151	0.050
-36.576	171.450	1.125	1.016	0.803	0.622	3.720	1.754	0.231	0.062
-36.576	177.800	1.167	1.026	0.816	0.622	3.066	1.871	0.121	0.037
-36.574	184.150	1.208	1.028	0.823	0.616	3.460	1.848	0.044	0.012
-36.576	190.502	1.250	1.031	0.831	0.609	3.479	1.726	0.145	0.042
-36.576	196.850	1.292	1.035	0.839	0.606	2.811	1.710	0.103	0.037
-36.576	203.200	1.333	1.033	0.839	0.602	4.114	1.819	0.126	0.029

Survey Number 2									
Station 1									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
-36.576	-6.350	-0.042	0.977	0.769	0.602	2.024	2.019	0.113	0.048
-36.574	0.000	0.000	0.983	0.769	0.611	1.947	1.895	0.205	0.097
-36.576	6.350	0.042	0.992	0.775	0.619	2.232	1.826	0.201	0.086
-36.574	12.700	0.083	1.005	0.789	0.622	2.597	1.860	0.129	0.047
-36.576	19.050	0.125	1.014	0.798	0.626	3.168	2.064	0.162	0.043
-36.576	25.400	0.167	1.019	0.805	0.624	2.554	1.961	0.160	0.056
-36.574	31.750	0.208	1.019	0.810	0.619	2.844	2.099	0.214	0.063
-36.574	38.100	0.250	1.024	0.818	0.616	1.939	1.922	0.029	0.013
-36.576	44.450	0.292	1.024	0.824	0.608	3.161	2.170	0.110	0.028
-36.576	50.800	0.333	1.021	0.826	0.600	3.009	2.051	0.113	0.032
-36.576	57.150	0.375	1.019	0.826	0.595	2.716	2.110	0.181	0.055
-36.576	63.500	0.417	1.018	0.830	0.590	2.497	2.694	0.129	0.034
-36.574	69.850	0.458	1.018	0.832	0.587	2.219	2.230	0.242	0.086
-36.574	76.200	0.500	1.010	0.827	0.580	2.045	2.333	0.192	0.070
-36.576	82.550	0.542	1.000	0.819	0.573	1.833	2.242	0.104	0.044
-36.576	88.900	0.583	0.993	0.815	0.568	1.983	2.039	0.139	0.060
-36.574	95.250	0.625	0.989	0.810	0.567	1.894	2.022	0.167	0.076
-36.576	101.600	0.667	0.983	0.802	0.568	1.850	2.076	0.122	0.056
-36.576	107.950	0.708	0.978	0.795	0.570	1.862	2.156	0.217	0.094
-36.576	114.300	0.750	0.971	0.787	0.570	1.922	3.067	0.213	0.063
-36.576	120.650	0.792	0.970	0.783	0.572	2.182	2.268	0.148	0.052
-36.576	127.000	0.833	0.970	0.781	0.576	2.204	2.060	0.198	0.076
-36.576	133.350	0.875	0.969	0.775	0.582	1.931	2.247	0.178	0.072
-36.574	139.700	0.917	0.971	0.772	0.589	2.065	1.944	0.121	0.052
-36.576	146.050	0.958	0.977	0.772	0.599	2.050	2.221	0.164	0.063
-36.576	152.400	1.000	0.984	0.773	0.609	1.857	1.965	0.159	0.076
-36.576	158.750	1.042	0.991	0.777	0.614	1.997	2.108	0.225	0.093

Survey Number 3									
Station 2									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
-18.288	-25.400	-0.167	0.946	0.766	0.555	1.993	2.013	0.246	0.108
-18.288	-22.860	-0.150	0.943	0.761	0.557	2.014	1.896	0.319	0.147
-18.288	-20.320	-0.133	0.941	0.754	0.562	1.967	1.977	0.215	0.098
-18.288	-17.780	-0.117	0.942	0.751	0.568	1.903	1.852	0.176	0.088
-18.288	-15.240	-0.100	0.942	0.747	0.574	1.806	1.821	0.169	0.091
-18.288	-12.700	-0.083	0.941	0.741	0.580	1.795	1.805	0.146	0.079
-18.288	-10.160	-0.067	0.942	0.736	0.588	1.801	1.826	0.257	0.138
-18.288	-7.620	-0.050	0.945	0.732	0.597	1.831	1.778	0.201	0.109
-18.288	-5.080	-0.033	0.946	0.728	0.604	1.854	1.729	0.168	0.092
-18.288	-2.540	-0.017	0.952	0.727	0.615	1.860	1.647	0.044	0.025
-18.288	0.000	0.000	0.960	0.729	0.625	1.826	1.665	0.109	0.064
-18.288	2.540	0.017	0.970	0.733	0.634	1.775	1.670	0.100	0.059
-18.288	5.080	0.033	0.982	0.741	0.645	1.722	1.910	0.074	0.040
-18.288	7.620	0.050	0.995	0.749	0.655	1.750	1.827	0.137	0.076
-18.288	10.160	0.067	1.008	0.761	0.660	1.787	1.849	0.123	0.066
-18.288	12.700	0.083	1.020	0.772	0.667	1.749	1.807	0.093	0.052
-18.288	15.240	0.100	1.033	0.786	0.670	1.818	1.853	0.013	0.007
-18.288	17.780	0.117	1.040	0.796	0.669	1.950	1.944	0.228	0.106
-18.288	20.320	0.133	1.050	0.807	0.671	1.958	1.763	0.180	0.092
-18.288	22.860	0.150	1.055	0.817	0.668	2.024	1.768	0.122	0.060
-18.288	25.400	0.167	1.061	0.827	0.664	1.947	1.807	0.134	0.067
-18.288	27.940	0.183	1.064	0.835	0.660	2.056	1.791	0.097	0.047
-18.288	30.480	0.200	1.068	0.843	0.656	2.238	2.147	0.158	0.058
-18.288	33.020	0.217	1.069	0.849	0.650	1.982	1.919	0.155	0.072
-18.288	35.560	0.233	1.069	0.857	0.639	1.894	1.895	0.017	0.008
-18.288	38.100	0.250	1.067	0.860	0.632	1.827	1.980	0.088	0.043
-18.288	40.640	0.267	1.067	0.864	0.626	1.871	1.704	0.098	0.054
-18.288	43.180	0.283	1.065	0.867	0.620	1.924	1.630	0.075	0.042
-18.288	45.720	0.300	1.065	0.870	0.615	1.917	1.615	0.124	0.071
-18.288	48.260	0.317	1.063	0.870	0.610	1.896	1.653	0.065	0.037
-18.288	50.800	0.333	1.060	0.871	0.604	1.843	1.911	0.041	0.021
-18.288	53.340	0.350	1.060	0.873	0.602	1.748	1.683	0.019	0.012
-18.288	55.880	0.367	1.056	0.872	0.596	1.715	1.738	0.005	0.003
-18.288	58.420	0.383	1.052	0.871	0.590	1.766	1.732	0.195	0.113
-18.288	60.960	0.400	1.046	0.868	0.584	1.763	1.964	0.097	0.050
-18.288	63.500	0.417	1.042	0.865	0.580	1.803	1.818	0.155	0.084
-18.288	66.040	0.433	1.039	0.866	0.575	1.833	1.763	0.203	0.111
-18.288	68.580	0.450	1.032	0.860	0.570	1.855	1.766	0.108	0.058
-18.288	71.120	0.467	1.030	0.861	0.566	2.018	1.745	0.204	0.102
-18.288	73.660	0.483	1.025	0.858	0.561	2.015	1.924	0.192	0.087
-18.288	76.200	0.500	1.024	0.857	0.560	2.094	1.988	0.207	0.088
-18.288	78.740	0.517	1.020	0.854	0.557	2.143	1.996	0.242	0.100
-18.288	81.280	0.533	1.016	0.852	0.554	1.911	1.825	0.266	0.135
-18.288	83.820	0.550	1.011	0.848	0.550	1.873	1.866	0.218	0.110
-18.288	86.360	0.567	1.006	0.844	0.548	1.872	1.975	0.190	0.091
-18.288	88.900	0.583	1.002	0.841	0.546	1.928	2.013	0.133	0.060
-18.288	91.440	0.600	0.994	0.832	0.544	1.739	2.009	0.241	0.122
-18.288	93.980	0.617	0.988	0.827	0.540	1.730	2.004	0.148	0.075
-18.288	96.520	0.633	0.982	0.822	0.537	1.720	1.787	0.120	0.069
-18.288	99.060	0.650	0.979	0.818	0.537	1.858	1.746	0.157	0.085
-18.288	101.600	0.667	0.974	0.814	0.536	1.886	1.910	0.213	0.104
-18.288	104.138	0.683	0.970	0.809	0.535	1.810	1.830	0.122	0.065
-18.288	106.680	0.700	0.968	0.806	0.537	1.816	1.896	0.136	0.070
-18.288	109.220	0.717	0.964	0.800	0.538	1.955	1.635	0.134	0.074
-18.288	111.760	0.733	0.963	0.800	0.536	1.850	1.762	0.128	0.069
-18.288	114.300	0.750	0.960	0.798	0.533	1.840	1.784	0.096	0.052
-18.288	116.840	0.767	0.956	0.792	0.536	1.812	1.800	0.173	0.093
-18.288	119.380	0.783	0.952	0.785	0.538	1.888	1.779	0.172	0.091
-18.288	121.920	0.800	0.951	0.783	0.540	1.993	1.692	0.183	0.096
-18.288	124.460	0.817	0.947	0.776	0.542	1.911	1.904	0.211	0.102
-18.288	127.000	0.833	0.945	0.771	0.547	1.858	1.782	0.248	0.132
-18.288	129.540	0.850	0.944	0.766	0.552	2.029	1.733	0.256	0.129
-18.288	132.080	0.867	0.943	0.761	0.556	1.959	1.699	0.166	0.088
-18.288	134.620	0.883	0.942	0.756	0.561	1.841	1.741	0.115	0.063
-18.288	137.160	0.900	0.943	0.754	0.567	1.825	1.907	0.073	0.037
-18.288	139.700	0.917	0.941	0.747	0.573	1.842	1.717	0.129	0.072
-18.288	142.240	0.933	0.943	0.743	0.581	1.777	1.708	0.094	0.054
-18.288	144.780	0.950	0.944	0.738	0.589	1.775	1.739	0.130	0.075
-18.288	147.320	0.967	0.947	0.735	0.597	1.716	1.622	0.048	0.030
-18.288	149.860	0.983	0.955	0.736	0.609	1.778	1.732	0.091	0.052
-18.288	152.400	1.000	0.963	0.738	0.620	1.734	1.537	0.096	0.063
-18.288	154.940	1.017	0.974	0.743	0.630	1.814	1.706	0.222	0.126
-18.288	157.480	1.033	0.986	0.748	0.642	1.979	1.697	0.095	0.050
-18.288	160.020	1.050	0.998	0.756	0.651	1.740	1.988	0.038	0.019
-18.288	162.560	1.067	1.010	0.766	0.658	1.782	1.936	0.052	0.027
-18.288	165.100	1.083	1.021	0.776	0.664	1.784	1.849	0.096	0.051
-18.288	167.640	1.100	1.032	0.786	0.668	1.788	1.897	0.162	0.084
-18.288	170.180	1.117	1.041	0.800	0.667	1.743	1.822	0.043	0.024
-18.288	172.720	1.133	1.049	0.809	0.667	1.869	2.117	0.248	0.111
-18.290	175.260	1.150	1.053	0.817	0.665	1.832	1.848	0.143	0.075
-18.288	177.800	1.167	1.060	0.828	0.663	1.940	1.721	0.121	0.064

Survey Number 4									
Station 2 with Laser Pitch									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
-18.288	-25.400	-0.167	0.936	0.758	0.550	1.980	1.846	0.391	0.189
-18.288	-20.320	-0.133	0.934	0.748	0.560	1.946	1.799	0.251	0.127
-18.288	-15.240	-0.100	0.933	0.739	0.570	1.958	1.751	0.237	0.122
-18.288	-10.160	-0.067	0.937	0.733	0.585	1.846	1.792	0.241	0.129
-18.288	-5.080	-0.033	0.944	0.726	0.603	1.835	1.686	0.116	0.066
-18.288	0.000	0.000	0.956	0.726	0.622	1.778	1.551	0.121	0.078
-18.288	5.080	0.033	0.978	0.736	0.644	1.733	1.670	0.075	0.046
-18.288	10.160	0.067	1.005	0.757	0.660	1.752	1.709	0.160	0.094
-18.288	15.240	0.100	1.027	0.778	0.670	1.785	1.723	0.108	0.062
-18.288	20.320	0.133	1.043	0.800	0.669	1.841	1.807	0.161	0.085
-18.288	25.398	0.167	1.060	0.827	0.663	1.991	1.936	0.294	0.135
-18.288	30.480	0.200	1.069	0.846	0.653	2.040	1.809	0.264	0.126
-18.288	35.560	0.233	1.069	0.855	0.641	1.869	1.985	0.236	0.112
-18.288	40.640	0.267	1.067	0.861	0.630	1.799	1.802	0.100	0.054
-18.288	45.720	0.300	1.062	0.865	0.616	1.776	1.668	0.107	0.064
-18.288	50.800	0.333	1.054	0.864	0.605	1.792	1.583	0.101	0.063
-18.288	55.880	0.367	1.048	0.863	0.594	1.786	1.618	0.201	0.123
-18.288	60.960	0.400	1.045	0.866	0.586	1.795	1.661	0.150	0.089
-18.288	66.040	0.433	1.036	0.862	0.574	1.884	1.689	0.177	0.098
-18.288	71.120	0.467	1.028	0.860	0.563	2.069	1.740	0.182	0.090
-18.286	76.200	0.500	1.023	0.858	0.557	2.039	1.800	0.184	0.089
-18.286	81.280	0.533	1.015	0.851	0.552	1.914	1.813	0.174	0.089
-18.288	86.360	0.567	1.003	0.842	0.544	1.830	1.936	0.296	0.148
-18.288	91.440	0.600	0.992	0.832	0.540	1.745	1.783	0.194	0.110
-18.288	96.520	0.633	0.979	0.822	0.533	1.760	1.740	0.205	0.118
-18.288	101.600	0.667	0.972	0.813	0.533	1.771	1.647	0.118	0.072
-18.288	106.680	0.700	0.966	0.806	0.533	1.795	1.682	0.078	0.046
-18.288	111.758	0.733	0.958	0.796	0.533	1.769	1.640	0.128	0.078
-18.288	116.840	0.767	0.947	0.782	0.534	1.794	1.693	0.126	0.073
-18.290	121.920	0.800	0.941	0.771	0.539	1.775	1.681	0.200	0.119
-18.288	127.000	0.833	0.938	0.763	0.545	2.089	1.677	0.277	0.140
-18.288	132.080	0.867	0.937	0.754	0.555	1.940	1.571	0.221	0.128
-18.288	137.160	0.900	0.939	0.752	0.563	1.811	1.787	0.167	0.091
-18.288	142.240	0.933	0.940	0.742	0.576	1.682	1.821	0.127	0.073
-18.288	147.320	0.967	0.943	0.735	0.591	1.769	1.611	0.149	0.092
-18.288	152.400	1.000	0.958	0.736	0.614	1.739	1.564	0.087	0.056
-18.288	157.480	1.033	0.980	0.746	0.635	1.758	1.608	0.051	0.032
-18.288	162.560	1.067	1.005	0.764	0.653	1.713	1.680	0.025	0.015
-18.288	167.640	1.100	1.022	0.782	0.658	1.799	1.778	0.146	0.081
-18.288	172.720	1.133	1.041	0.805	0.660	1.939	1.967	0.085	0.040
-18.288	177.802	1.167	1.056	0.826	0.657	2.042	1.753	0.183	0.090

Survey Number 5								
Station 3								
x(mm)	y(mm)	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
-6.096	10.000	1.057	0.728	0.766	1.667	1.831	0.129	0.074
-6.096	12.000	1.076	0.756	0.766	1.797	2.136	0.145	0.066
-6.096	14.000	1.089	0.778	0.762	2.072	1.894	0.220	0.099
-6.096	16.000	1.101	0.800	0.757	1.795	1.988	0.117	0.057
-6.096	18.000	1.107	0.816	0.749	1.781	2.020	0.073	0.036
-6.098	20.000	1.113	0.833	0.739	1.844	2.156	0.032	0.014
-6.098	22.000	1.116	0.843	0.731	1.989	1.945	0.111	0.051
-6.096	24.000	1.116	0.854	0.718	1.776	1.945	0.009	0.004
-6.096	26.000	1.121	0.865	0.713	1.780	1.763	0.099	0.055
-6.098	28.000	1.120	0.873	0.702	1.830	1.793	0.086	0.046
-6.096	30.000	1.121	0.880	0.694	1.912	1.805	0.100	0.051
-6.096	32.000	1.123	0.890	0.684	1.950	1.723	0.097	0.051
-6.094	34.000	1.121	0.895	0.675	2.001	1.962	0.122	0.055
-6.096	36.000	1.119	0.899	0.667	1.935	2.014	-0.018	-0.008
-6.096	38.000	1.116	0.903	0.657	1.996	2.083	0.125	0.053
-6.096	40.000	1.115	0.907	0.648	1.876	1.828	0.143	0.073
-6.096	42.000	1.110	0.906	0.640	1.855	1.836	0.224	0.116
-6.094	44.000	1.105	0.907	0.631	1.898	1.794	0.249	0.129
-6.094	46.000	1.102	0.908	0.625	1.836	1.732	0.029	0.016
-6.096	48.000	1.097	0.907	0.617	1.817	1.754	0.113	0.062
-6.096	50.000	1.094	0.907	0.612	2.058	1.848	0.127	0.059
-6.096	52.000	1.089	0.905	0.605	1.814	1.725	0.203	0.114
-6.096	54.000	1.084	0.904	0.598	1.752	1.738	0.111	0.064
-6.096	56.000	1.077	0.900	0.591	1.763	1.756	0.043	0.024
-6.096	58.000	1.072	0.899	0.584	1.743	1.757	0.102	0.059
-6.096	60.000	1.069	0.898	0.580	1.807	1.688	0.080	0.046
-6.096	62.000	1.063	0.895	0.573	1.815	1.913	0.118	0.060
-6.096	64.000	1.058	0.893	0.566	1.837	1.821	0.001	0.001
-6.098	66.000	1.052	0.892	0.558	1.759	2.335	0.170	0.072
-6.096	68.000	1.051	0.891	0.556	1.794	1.764	0.143	0.079
-6.098	70.000	1.044	0.887	0.550	1.791	1.889	0.146	0.076
-6.096	72.000	1.039	0.885	0.544	1.803	1.994	0.096	0.047
-6.096	74.000	1.033	0.880	0.541	1.917	1.779	0.105	0.054
-6.096	76.000	1.029	0.878	0.538	2.020	1.912	0.184	0.084
-6.096	78.000	1.024	0.874	0.534	2.036	1.831	0.293	0.138
-6.096	80.000	1.019	0.869	0.531	2.068	1.742	0.307	0.149
-6.096	82.000	1.017	0.868	0.529	2.058	1.789	0.256	0.122
-6.096	84.000	1.012	0.864	0.527	2.005	1.795	0.347	0.169
-6.096	86.000	1.007	0.859	0.526	2.025	1.873	0.214	0.099
-6.096	88.000	1.003	0.856	0.523	1.888	1.829	0.221	0.112
-6.096	90.000	0.999	0.852	0.522	1.934	1.807	0.264	0.133
-6.096	92.000	0.995	0.848	0.519	1.831	1.882	0.261	0.133
-6.096	94.000	0.987	0.842	0.515	1.757	2.011	0.156	0.077
-6.096	96.002	0.983	0.837	0.516	1.805	2.070	0.163	0.077
-6.096	98.000	0.978	0.833	0.513	1.819	1.896	0.255	0.130
-6.096	99.998	0.972	0.827	0.511	1.741	1.858	0.155	0.084
-6.096	102.000	0.965	0.820	0.508	1.798	1.824	0.292	0.156
-6.096	104.000	0.958	0.814	0.505	1.784	1.950	0.198	0.100
-6.096	106.000	0.955	0.811	0.505	1.760	2.027	0.140	0.069
-6.096	108.000	0.950	0.805	0.505	1.862	1.840	0.157	0.080
-6.096	110.000	0.949	0.804	0.503	1.770	1.681	0.052	0.030
-6.096	112.000	0.946	0.801	0.502	2.026	1.774	0.205	0.100
-6.096	114.000	0.941	0.795	0.503	1.778	1.761	0.157	0.088
-6.096	116.000	0.937	0.790	0.504	1.917	1.653	0.240	0.133
-6.096	118.000	0.932	0.784	0.504	1.789	1.663	0.103	0.061
-6.096	120.000	0.927	0.777	0.505	1.892	1.771	0.179	0.094
-6.096	122.000	0.923	0.772	0.506	1.792	1.912	0.212	0.108
-6.094	124.000	0.918	0.765	0.508	1.787	1.737	0.239	0.135
-6.096	126.000	0.914	0.758	0.511	1.818	1.941	0.122	0.061
-6.096	128.000	0.910	0.752	0.513	1.864	1.902	0.161	0.079
-6.096	130.000	0.906	0.745	0.515	1.870	1.847	0.209	0.106
-6.098	132.000	0.903	0.739	0.520	1.897	1.814	0.288	0.147
-6.096	133.998	0.899	0.731	0.523	2.045	1.700	0.259	0.131
-6.096	136.000	0.893	0.723	0.525	2.029	1.695	0.422	0.215
-6.096	138.000	0.889	0.714	0.530	2.040	1.672	0.148	0.076
-6.096	140.000	0.887	0.706	0.536	2.080	1.574	0.303	0.162
-6.096	142.000	0.883	0.696	0.543	2.074	1.806	0.231	0.108
-6.096	144.000	0.877	0.683	0.550	1.995	1.837	0.338	0.162
-6.096	146.000	0.874	0.671	0.560	1.878	1.782	0.162	0.085
-6.096	148.000	0.874	0.659	0.574	1.774	1.792	0.114	0.063
-6.096	150.000	0.875	0.644	0.592	1.753	1.672	0.153	0.091
-6.096	151.342	0.879	0.635	0.608	1.759	1.598	0.121	0.076

Survey Number 6									
Station 3 with Laser Pitch									
x(mm)	y(mm)	y/S	W/V_{ref}	U/V_{ref}	V/V_{ref}	T_u	T_v	Re stress	Cuv
-6.096	-25.400	-0.167	0.907	0.751	0.509	1.927	1.744	0.118	0.062
-6.096	-22.860	-0.150	0.903	0.742	0.515	1.979	1.706	0.219	0.114
-6.096	-20.320	-0.133	0.895	0.732	0.516	2.004	1.801	0.351	0.171
-6.096	-17.780	-0.117	0.893	0.723	0.523	2.000	1.641	0.357	0.191
-6.096	-15.240	-0.100	0.887	0.712	0.529	2.068	1.632	0.320	0.167
-6.096	-12.700	-0.083	0.881	0.699	0.536	2.178	1.745	0.326	0.151
-6.096	-10.160	-0.067	0.874	0.685	0.543	2.018	1.761	0.366	0.181
-6.096	-7.620	-0.050	0.869	0.668	0.556	1.917	1.758	0.210	0.110
-6.096	-5.080	-0.033	0.866	0.653	0.569	1.846	1.778	0.170	0.091
-6.096	-2.540	-0.017	0.866	0.633	0.591	1.861	1.724	0.021	0.012
-6.096	0.000	0.000	0.877	0.614	0.625	1.774	1.614	0.071	0.044
-6.094	2.540	0.017	0.922	0.621	0.682	1.785	1.834	0.067	0.036
-6.094	5.080	0.033	0.973	0.650	0.724	1.655	1.714	0.059	0.037
-6.094	7.620	0.050	1.018	0.691	0.748	1.809	1.824	0.103	0.055
-6.094	10.160	0.067	1.052	0.730	0.758	1.694	1.773	0.128	0.075
-6.096	12.700	0.083	1.075	0.763	0.758	1.657	1.737	0.056	0.034
-6.096	15.240	0.100	1.092	0.792	0.751	1.775	1.778	0.068	0.038
-6.096	17.780	0.117	1.102	0.815	0.742	1.739	1.775	0.063	0.036
-6.094	20.320	0.133	1.108	0.833	0.730	1.828	1.719	0.077	0.043
-6.096	22.860	0.150	1.112	0.847	0.720	1.830	1.667	0.148	0.086
-6.096	25.402	0.167	1.116	0.862	0.709	1.794	1.640	0.077	0.046
-6.094	27.940	0.183	1.119	0.873	0.700	1.983	1.731	0.132	0.068
-6.096	30.480	0.200	1.116	0.881	0.685	2.013	1.766	0.206	0.102
-6.094	33.020	0.217	1.116	0.888	0.677	1.885	1.695	0.159	0.087
-6.094	35.558	0.233	1.116	0.895	0.667	1.994	1.772	0.249	0.124
-6.094	38.100	0.250	1.115	0.902	0.656	1.949	1.803	0.088	0.044
-6.096	40.640	0.267	1.110	0.905	0.643	1.902	1.818	0.211	0.107
-6.096	43.180	0.283	1.106	0.907	0.633	1.958	1.807	0.210	0.104
-6.096	45.720	0.300	1.101	0.908	0.622	1.845	1.846	0.049	0.025
-6.096	48.260	0.317	1.094	0.907	0.612	1.740	1.762	0.169	0.097
-6.096	50.800	0.333	1.089	0.906	0.604	1.783	1.790	0.095	0.052
-6.096	53.340	0.350	1.085	0.905	0.598	1.736	1.739	0.086	0.050
-6.096	55.880	0.367	1.075	0.900	0.588	1.804	1.791	0.056	0.030
-6.096	58.420	0.383	1.070	0.899	0.580	1.833	1.749	0.045	0.025
-6.096	60.960	0.400	1.063	0.895	0.574	1.865	1.663	0.099	0.056
-6.096	63.500	0.417	1.056	0.892	0.565	1.848	1.703	0.187	0.104
-6.096	66.040	0.433	1.050	0.888	0.560	1.883	1.709	0.172	0.094
-6.096	68.580	0.450	1.045	0.886	0.554	2.091	1.738	0.193	0.093
-6.096	71.120	0.467	1.037	0.881	0.548	2.270	1.776	0.160	0.070
-6.096	73.660	0.483	1.031	0.876	0.544	1.760	1.716	0.138	0.080
-6.096	76.200	0.500	1.025	0.871	0.539	1.816	1.773	0.224	0.122
-6.096	78.740	0.517	1.017	0.864	0.536	2.258	1.778	0.327	0.143
-6.096	81.280	0.533	1.015	0.863	0.533	2.014	1.821	0.359	0.172
-6.096	83.820	0.550	1.009	0.859	0.529	1.951	1.819	0.152	0.075
-6.094	86.360	0.567	1.001	0.852	0.526	2.092	1.863	0.378	0.171
-6.096	88.900	0.583	0.996	0.850	0.518	2.045	1.810	0.357	0.170
-6.096	91.440	0.600	0.994	0.850	0.515	1.778	1.861	0.368	0.195
-6.096	93.980	0.617	0.984	0.842	0.509	1.782	1.913	0.325	0.167
-6.096	96.520	0.633	0.975	0.833	0.506	1.724	1.850	0.229	0.126
-6.096	99.060	0.650	0.971	0.830	0.504	1.806	1.766	0.245	0.135
-6.096	101.600	0.667	0.964	0.822	0.503	1.788	1.749	0.159	0.089
-6.096	104.140	0.683	0.957	0.815	0.503	1.833	1.679	0.194	0.111
-6.096	106.680	0.700	0.953	0.809	0.504	1.822	1.658	0.035	0.020
-6.096	109.220	0.717	0.945	0.802	0.500	1.876	1.633	0.153	0.088
-6.096	111.760	0.733	0.941	0.796	0.501	1.930	1.594	0.115	0.066
-6.096	114.300	0.750	0.934	0.789	0.500	1.909	1.653	0.153	0.085
-6.094	116.840	0.767	0.930	0.783	0.503	1.762	1.694	0.196	0.115
-6.096	119.380	0.783	0.923	0.774	0.503	1.696	1.675	0.171	0.106
-6.096	121.920	0.800	0.917	0.765	0.504	1.774	1.649	0.139	0.084
-6.096	124.460	0.817	0.913	0.758	0.508	1.710	1.737	0.254	0.150
-6.096	126.998	0.833	0.906	0.748	0.510	1.730	1.754	0.178	0.103
-6.094	129.540	0.850	0.901	0.741	0.513	1.801	1.670	0.261	0.153
-6.096	132.080	0.867	0.897	0.732	0.518	1.809	1.758	0.323	0.178
-6.094	134.620	0.883	0.892	0.723	0.522	1.917	1.706	0.271	0.146
-6.096	137.160	0.900	0.883	0.709	0.526	2.047	1.683	0.292	0.149
-6.094	139.700	0.917	0.879	0.699	0.533	2.171	1.739	0.338	0.157
-6.096	142.240	0.933	0.875	0.687	0.542	2.076	1.873	0.376	0.170
-6.096	144.780	0.950	0.869	0.672	0.552	2.004	1.643	0.264	0.141
-6.096	147.320	0.967	0.866	0.655	0.567	1.919	1.604	0.170	0.097
-6.096	149.860	0.983	0.867	0.637	0.588	2.006	1.593	0.165	0.091
-6.096	152.400	1.000	0.880	0.623	0.622	1.913	1.579	0.100	0.058
-6.096	154.940	1.017	0.918	0.627	0.671	1.847	1.795	-0.051	-0.027
-6.096	157.480	1.033	0.968	0.652	0.715	1.715	1.821	0.040	0.023
-6.096	160.022	1.050	1.010	0.687	0.741	1.807	1.948	0.147	0.074
-6.096	162.560	1.067	1.048	0.727	0.754	1.827	1.900	0.012	0.006
-6.096	165.100	1.083	1.070	0.758	0.755	1.733	1.727	0.048	0.028
-6.094	167.640	1.100	1.088	0.787	0.750	1.821	1.771	0.117	0.064
-6.096	170.180	1.117	1.099	0.810	0.743	1.795	1.813	0.097	0.052
-6.094	172.720	1.133	1.109	0.831	0.735	1.850	1.668	0.033	0.019
-6.096	175.260	1.150	1.114	0.847	0.724	1.753	1.638	0.094	0.057
-6.096	177.800	1.167	1.117	0.860	0.712	1.824	1.662	0.037	0.021

Survey Number 7									
Station 4									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
0.002	15.160	0.099	1.171	0.830	0.826	1.892	2.393	0.135	0.052
0.002	16.000	0.105	1.171	0.838	0.817	1.935	2.118	0.160	0.068
0.002	18.000	0.118	1.172	0.858	0.799	2.011	2.265	0.113	0.043
0.000	20.000	0.131	1.171	0.871	0.782	1.921	1.783	-0.091	-0.046
0.000	22.000	0.144	1.172	0.885	0.767	1.879	2.121	0.086	0.038
0.000	24.000	0.157	1.168	0.895	0.750	1.852	2.599	-0.038	-0.014
0.000	26.000	0.171	1.164	0.902	0.736	1.807	1.783	0.040	0.021
0.000	28.000	0.184	1.159	0.907	0.722	1.845	2.115	0.097	0.043
0.000	30.000	0.197	1.160	0.916	0.711	1.874	2.159	0.046	0.020
0.000	32.000	0.210	1.156	0.921	0.700	1.988	1.949	0.223	0.100
0.000	34.000	0.223	1.152	0.925	0.687	1.889	2.140	0.174	0.075
0.000	36.000	0.236	1.148	0.931	0.671	2.026	1.837	0.179	0.084
0.000	38.000	0.249	1.144	0.934	0.660	1.996	2.128	0.064	0.026
0.000	40.000	0.262	1.140	0.937	0.650	1.925	1.875	0.003	0.001
0.000	42.000	0.276	1.135	0.939	0.639	1.879	1.940	0.125	0.060
0.000	44.000	0.289	1.127	0.936	0.627	1.984	1.894	0.080	0.037
0.002	46.000	0.302	1.122	0.936	0.618	1.842	1.769	0.086	0.046
0.002	48.000	0.315	1.118	0.937	0.611	1.809	1.850	0.110	0.058
0.000	50.000	0.328	1.113	0.934	0.606	1.791	1.882	0.113	0.058
0.000	52.000	0.341	1.106	0.932	0.597	1.807	1.983	0.089	0.044
0.002	54.000	0.354	1.099	0.928	0.588	1.719	2.053	0.137	0.068
0.000	56.000	0.367	1.093	0.926	0.581	1.778	1.794	0.051	0.028
0.002	58.000	0.381	1.085	0.921	0.573	1.761	1.785	0.135	0.075
-0.002	60.000	0.394	1.078	0.917	0.566	1.896	1.808	0.178	0.091
0.000	62.000	0.407	1.074	0.917	0.560	1.775	1.779	0.176	0.097
0.000	64.000	0.420	1.065	0.910	0.553	1.876	1.647	0.131	0.074
-0.002	66.000	0.433	1.063	0.909	0.551	1.822	1.690	0.100	0.056
0.000	68.002	0.446	1.056	0.904	0.545	1.782	1.784	0.016	0.009
0.000	70.000	0.459	1.050	0.899	0.542	1.770	1.662	0.136	0.081
0.000	72.000	0.472	1.043	0.896	0.534	1.780	1.781	0.140	0.077
0.000	74.000	0.486	1.037	0.890	0.531	1.775	1.796	0.240	0.131
0.000	76.000	0.499	1.029	0.884	0.526	1.806	1.828	0.233	0.123
0.000	78.000	0.512	1.023	0.880	0.522	1.825	1.840	0.188	0.098
0.000	80.000	0.525	1.020	0.877	0.519	1.859	1.752	0.153	0.082
0.000	82.000	0.538	1.013	0.871	0.516	1.983	1.946	0.255	0.115
0.000	84.000	0.551	1.007	0.866	0.513	1.942	1.857	0.203	0.098
0.000	86.000	0.564	1.003	0.864	0.510	2.031	1.840	0.283	0.132
0.000	88.000	0.577	1.002	0.866	0.504	1.909	1.861	0.256	0.126
0.000	90.000	0.591	0.998	0.863	0.501	1.982	1.848	0.194	0.092
0.002	92.000	0.604	0.991	0.856	0.499	1.822	1.910	0.171	0.086
0.000	94.000	0.617	0.985	0.850	0.498	1.790	1.804	0.252	0.136
0.000	96.000	0.630	0.978	0.844	0.494	1.842	1.907	0.225	0.112
0.000	98.000	0.643	0.971	0.837	0.492	1.799	1.852	0.275	0.144
0.000	100.000	0.656	0.966	0.832	0.490	1.754	1.997	0.318	0.159
0.000	102.000	0.669	0.959	0.825	0.489	1.832	1.760	0.204	0.110
0.000	104.000	0.682	0.950	0.816	0.487	1.763	1.827	0.171	0.092
0.000	106.000	0.696	0.944	0.809	0.485	1.825	1.862	0.207	0.106
0.000	108.000	0.709	0.940	0.806	0.484	1.839	1.701	0.105	0.059
0.002	110.000	0.722	0.936	0.800	0.486	1.852	1.737	0.118	0.064
0.000	112.000	0.735	0.929	0.792	0.485	1.878	1.869	0.137	0.068
0.002	114.000	0.748	0.925	0.788	0.485	1.890	1.647	0.120	0.067
0.000	116.000	0.761	0.920	0.781	0.485	1.901	1.693	0.187	0.101
-0.002	118.000	0.774	0.915	0.775	0.486	1.837	1.713	0.102	0.057
-0.002	120.000	0.787	0.912	0.771	0.488	1.808	1.624	0.119	0.071
0.000	122.000	0.801	0.906	0.763	0.488	1.810	1.672	0.095	0.055
0.000	124.000	0.814	0.899	0.755	0.490	1.709	1.664	0.145	0.089
0.000	126.000	0.827	0.894	0.748	0.490	1.995	1.769	0.157	0.078
0.000	128.000	0.840	0.889	0.741	0.492	1.709	1.846	0.155	0.086
0.000	130.000	0.853	0.885	0.733	0.495	1.776	1.768	0.167	0.093
0.000	132.000	0.866	0.876	0.723	0.494	1.808	1.774	0.299	0.163
0.000	134.000	0.879	0.868	0.713	0.494	1.873	2.092	0.321	0.143
0.000	136.000	0.892	0.862	0.703	0.497	1.960	1.699	0.378	0.198
0.000	138.000	0.906	0.854	0.692	0.499	2.003	1.741	0.190	0.095
0.002	140.000	0.919	0.847	0.682	0.502	2.017	1.698	0.375	0.191
0.000	142.000	0.932	0.838	0.669	0.505	1.986	1.822	0.147	0.071
0.002	144.000	0.945	0.829	0.657	0.505	1.910	1.697	0.257	0.138
0.000	144.920	0.951	0.823	0.649	0.507	1.983	1.871	0.259	0.122

Survey Number 8									
Station 5									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
6.098	22.400	0.147	1.232	0.946	0.789	2.010	2.206	0.157	0.062
6.098	24.000	0.157	1.226	0.952	0.773	2.008	2.132	0.119	0.048
6.096	26.000	0.171	1.220	0.957	0.757	2.036	2.412	-0.007	-0.003
6.096	28.000	0.184	1.213	0.962	0.739	2.045	2.421	-0.178	-0.063
6.094	30.000	0.197	1.208	0.967	0.724	1.981	1.878	0.085	0.040
6.096	32.000	0.210	1.199	0.967	0.708	1.943	1.770	0.165	0.084
6.096	34.000	0.223	1.194	0.972	0.694	1.968	2.085	0.059	0.025
6.096	36.002	0.236	1.187	0.972	0.680	1.975	2.315	0.052	0.020
6.096	38.000	0.249	1.176	0.970	0.666	1.979	2.128	0.219	0.090
6.096	40.000	0.262	1.170	0.971	0.652	2.005	2.212	-0.114	-0.045
6.096	42.000	0.276	1.163	0.971	0.640	2.064	1.975	0.193	0.082
6.096	44.000	0.289	1.160	0.975	0.628	2.032	1.810	0.040	0.019
6.098	46.000	0.302	1.151	0.972	0.617	1.933	1.821	0.045	0.022
6.096	48.000	0.315	1.146	0.971	0.610	2.017	1.787	0.137	0.066
6.098	50.000	0.328	1.140	0.968	0.603	1.905	1.885	0.211	0.102
6.096	52.000	0.341	1.132	0.965	0.592	1.850	2.178	0.124	0.054
6.096	54.000	0.354	1.125	0.961	0.584	1.947	1.881	0.192	0.091
6.098	56.002	0.367	1.116	0.957	0.574	1.893	2.043	0.128	0.058
6.096	58.000	0.381	1.106	0.950	0.566	1.839	1.872	0.115	0.058
6.096	60.000	0.394	1.099	0.945	0.561	1.888	2.021	0.204	0.093
6.096	62.000	0.407	1.092	0.942	0.554	1.811	2.007	0.028	0.013
6.096	64.000	0.420	1.080	0.933	0.543	1.784	1.819	0.198	0.106
6.098	66.000	0.433	1.075	0.931	0.538	1.820	1.701	0.048	0.027
6.096	68.000	0.446	1.070	0.927	0.533	1.822	1.708	0.202	0.113
6.096	70.000	0.459	1.062	0.922	0.529	1.787	1.640	0.093	0.055
6.096	72.000	0.472	1.054	0.915	0.523	1.848	1.772	0.056	0.030
6.096	74.000	0.486	1.047	0.911	0.518	2.026	1.810	0.225	0.107
6.094	76.000	0.499	1.041	0.906	0.513	1.744	1.775	0.106	0.059
6.096	78.000	0.512	1.034	0.900	0.509	1.782	1.844	0.189	0.100
6.096	80.000	0.525	1.026	0.894	0.504	1.879	1.831	0.140	0.071
6.096	82.000	0.538	1.022	0.893	0.497	1.976	1.718	0.117	0.060
6.096	84.002	0.551	1.016	0.887	0.496	1.891	1.738	0.170	0.090
6.096	86.000	0.564	1.012	0.885	0.491	2.058	1.757	0.207	0.099
6.096	88.000	0.577	1.007	0.880	0.491	2.039	1.739	0.234	0.115
6.096	90.000	0.591	0.999	0.871	0.488	2.068	1.764	0.290	0.139
6.096	92.000	0.604	0.994	0.867	0.485	1.995	1.887	0.288	0.133
6.096	94.000	0.617	0.988	0.863	0.481	1.890	1.767	0.251	0.131
6.096	95.998	0.630	0.982	0.856	0.480	1.902	1.860	0.156	0.077
6.096	98.000	0.643	0.975	0.849	0.478	2.024	1.792	0.243	0.117
6.096	100.000	0.656	0.968	0.843	0.475	1.930	1.895	0.262	0.125
6.096	102.000	0.669	0.960	0.835	0.473	1.733	1.846	0.191	0.104
6.096	104.000	0.682	0.954	0.830	0.470	1.744	1.963	0.388	0.197
6.096	106.000	0.696	0.945	0.821	0.468	1.716	1.861	0.233	0.127
6.096	108.000	0.709	0.937	0.812	0.467	1.761	1.882	0.238	0.125
6.096	110.000	0.722	0.932	0.806	0.466	1.805	1.754	0.220	0.121
6.096	112.000	0.735	0.925	0.798	0.466	1.773	1.728	0.238	0.135
6.096	114.000	0.748	0.919	0.792	0.466	1.806	1.709	0.214	0.121
6.096	116.000	0.761	0.912	0.785	0.464	1.828	1.642	0.134	0.078
6.096	118.000	0.774	0.908	0.780	0.465	1.888	1.695	0.236	0.129
6.096	120.000	0.787	0.902	0.772	0.466	1.931	1.715	0.242	0.127
6.098	122.000	0.801	0.897	0.766	0.467	1.869	2.120	0.301	0.132
6.098	124.000	0.814	0.891	0.758	0.467	1.840	1.632	0.180	0.104
6.096	126.000	0.827	0.883	0.749	0.467	1.812	1.665	0.242	0.140
6.096	128.000	0.840	0.877	0.743	0.467	1.728	1.653	0.132	0.081
6.098	130.000	0.853	0.872	0.736	0.468	1.706	1.716	0.172	0.102
6.096	132.000	0.866	0.864	0.726	0.468	1.820	1.669	0.241	0.138
6.098	134.000	0.879	0.855	0.715	0.468	1.767	1.757	0.290	0.162
6.096	136.000	0.892	0.846	0.704	0.469	1.774	1.970	0.320	0.159
6.096	138.000	0.906	0.838	0.694	0.470	1.928	1.750	0.298	0.154
6.096	140.000	0.919	0.825	0.679	0.468	1.886	1.813	0.331	0.168
6.096	142.000	0.932	0.819	0.671	0.469	1.817	1.681	0.190	0.108
6.096	144.000	0.945	0.807	0.658	0.466	1.862	1.863	0.325	0.163
6.096	144.680	0.949	0.804	0.655	0.466	1.871	1.734	0.412	0.221

Survey Number 9									
Station 5 Boundary Layer Survey									
x	y	d/c	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
4.970	10.682	0.012	1.245	0.821	0.936	3.482	6.894	4.148	0.305
4.596	11.012	0.016	1.241	0.809	0.941	2.936	2.727	1.584	0.349
4.220	11.342	0.020	1.240	0.824	0.926	2.778	3.050	1.508	0.314
3.846	11.672	0.024	1.238	0.834	0.915	2.113	1.818	0.297	0.136
3.470	12.004	0.028	1.227	0.833	0.901	1.956	2.396	0.059	0.022
3.096	12.334	0.032	1.220	0.832	0.892	1.954	2.165	0.215	0.090
2.718	12.664	0.035	1.214	0.832	0.885	1.894	1.696	0.101	0.056
2.344	12.996	0.039	1.206	0.831	0.875	1.833	1.698	0.109	0.062
1.970	13.326	0.043	1.199	0.830	0.865	1.874	1.766	0.167	0.089
1.594	13.656	0.047	1.194	0.831	0.857	1.850	1.839	0.226	0.117
1.220	13.988	0.051	1.185	0.828	0.847	1.868	2.096	0.197	0.089
0.846	14.320	0.055	1.180	0.830	0.839	1.832	1.779	0.147	0.080
0.470	14.648	0.059	1.174	0.830	0.829	1.895	1.862	0.154	0.077
0.094	14.980	0.063	1.167	0.829	0.821	1.732	1.816	0.032	0.018
-0.282	15.310	0.067	1.162	0.828	0.816	1.810	1.675	0.092	0.054
-0.658	15.640	0.071	1.157	0.829	0.807	1.716	1.844	0.086	0.048
-1.032	15.972	0.075	1.155	0.831	0.802	1.796	1.682	-0.010	-0.006
-1.406	16.302	0.079	1.132	0.810	0.792	2.280	2.116	0.304	0.111
-1.780	16.634	0.083	1.148	0.832	0.790	1.790	1.663	0.171	0.101
-2.156	16.964	0.087	1.144	0.832	0.784	1.837	2.423	0.042	0.017
-2.532	17.296	0.091	1.140	0.834	0.778	1.763	1.691	0.032	0.019
-2.906	17.626	0.095	1.136	0.833	0.773	1.790	1.696	0.045	0.026
-3.280	17.956	0.098	1.133	0.834	0.767	1.818	1.725	0.048	0.027
-3.656	18.286	0.102	1.130	0.836	0.761	1.699	1.737	0.032	0.019
-4.032	18.618	0.106	1.127	0.836	0.756	1.764	1.777	0.093	0.052
-4.406	18.948	0.110	1.123	0.834	0.752	1.730	1.727	0.138	0.081
-4.782	19.278	0.114	1.118	0.835	0.744	1.696	1.897	0.175	0.096
-5.156	19.610	0.118	1.117	0.835	0.742	1.663	1.744	0.001	0.001
-5.532	19.940	0.122	1.113	0.833	0.737	1.688	1.852	0.161	0.091
-5.908	20.272	0.126	1.111	0.835	0.733	1.712	1.782	0.185	0.107
-6.282	20.602	0.130	1.110	0.836	0.729	1.780	1.995	0.213	0.106

Survey Number 10									
Station 6									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
30.480	37.700	0.247	1.306	1.154	0.613	1.661	1.873	-0.116	-0.066
30.480	38.000	0.249	1.306	1.154	0.612	1.591	1.825	-0.118	-0.071
30.482	40.000	0.262	1.291	1.148	0.591	1.671	1.902	0.022	0.012
30.480	42.000	0.276	1.278	1.141	0.575	1.772	1.877	-0.080	-0.042
30.480	44.000	0.289	1.263	1.132	0.561	1.655	1.799	-0.017	-0.010
30.480	46.002	0.302	1.249	1.124	0.545	1.743	1.987	0.125	0.063
30.480	48.000	0.315	1.235	1.114	0.533	1.705	1.811	0.094	0.053
30.480	50.000	0.328	1.221	1.104	0.520	1.793	1.850	0.023	0.012
30.480	52.000	0.341	1.204	1.090	0.510	1.763	2.336	0.104	0.044
30.480	54.000	0.354	1.192	1.081	0.502	1.856	2.034	0.147	0.068
30.480	56.000	0.367	1.179	1.072	0.491	1.849	2.069	0.208	0.095
30.478	58.000	0.381	1.166	1.062	0.482	1.914	1.885	0.141	0.069
30.480	60.000	0.394	1.151	1.049	0.472	2.361	2.040	0.291	0.106
30.480	62.000	0.407	1.137	1.038	0.466	3.201	1.931	0.164	0.046
30.480	64.000	0.420	1.125	1.027	0.459	3.301	1.903	0.212	0.059
30.482	66.000	0.433	1.115	1.022	0.446	2.453	1.945	0.207	0.076
30.480	68.000	0.446	1.102	1.010	0.440	2.492	2.098	0.221	0.074
30.480	70.000	0.459	1.091	1.000	0.436	1.945	1.924	0.260	0.122
30.480	72.000	0.472	1.078	0.989	0.430	1.916	1.855	0.234	0.115
30.480	74.000	0.486	1.068	0.980	0.425	1.868	1.930	0.139	0.068
30.480	75.998	0.499	1.055	0.968	0.420	1.839	1.814	0.082	0.043
30.480	78.000	0.512	1.043	0.957	0.415	1.830	1.679	0.206	0.117
30.480	80.000	0.525	1.034	0.948	0.412	1.861	1.758	0.159	0.085
30.480	82.000	0.538	1.024	0.939	0.410	1.836	1.763	0.146	0.079
30.480	84.000	0.551	1.017	0.932	0.407	1.690	1.749	0.135	0.080
30.480	86.000	0.564	1.006	0.921	0.403	2.269	1.739	0.123	0.055
30.480	88.000	0.577	0.996	0.912	0.400	1.709	1.683	0.106	0.065
30.480	90.000	0.591	0.987	0.903	0.397	1.661	1.747	0.241	0.145
30.480	92.000	0.604	0.978	0.895	0.395	1.724	1.797	0.164	0.093
30.480	94.000	0.617	0.970	0.887	0.393	1.789	1.759	0.186	0.103
30.482	96.000	0.630	0.965	0.884	0.388	1.965	1.896	0.229	0.108
30.480	98.000	0.643	0.956	0.874	0.386	2.066	1.723	0.216	0.106
30.480	100.000	0.656	0.949	0.868	0.384	2.037	1.715	0.325	0.163
30.482	102.000	0.669	0.943	0.861	0.383	1.974	1.720	0.276	0.142
30.480	104.000	0.682	0.938	0.855	0.384	2.003	1.795	0.347	0.169
30.480	106.000	0.696	0.927	0.845	0.381	1.887	1.817	0.275	0.141
30.480	108.000	0.709	0.921	0.838	0.381	1.904	1.881	0.245	0.120
30.480	110.000	0.722	0.912	0.829	0.379	2.013	1.791	0.182	0.089
30.480	112.000	0.735	0.904	0.821	0.377	1.796	1.925	0.406	0.206
30.482	114.000	0.748	0.896	0.814	0.374	1.821	1.993	0.346	0.167
30.480	116.000	0.761	0.888	0.805	0.374	1.709	2.021	0.284	0.144
30.480	118.000	0.774	0.879	0.796	0.372	1.754	1.803	0.367	0.203
30.482	119.998	0.787	0.869	0.786	0.371	1.823	1.875	0.443	0.227
30.480	122.000	0.801	0.858	0.775	0.367	1.727	1.848	0.279	0.153
30.480	124.000	0.814	0.850	0.767	0.367	1.829	1.925	0.252	0.126
30.480	126.000	0.827	0.842	0.759	0.364	1.715	1.827	0.246	0.138
30.478	128.000	0.840	0.833	0.750	0.363	1.752	1.718	0.246	0.144
30.480	130.000	0.853	0.826	0.742	0.362	1.713	1.699	0.090	0.054
30.480	132.000	0.866	0.820	0.736	0.361	1.858	1.601	0.217	0.128
30.480	134.000	0.879	0.812	0.729	0.359	1.798	1.576	0.257	0.159
30.480	136.000	0.892	0.803	0.719	0.358	1.914	1.617	0.242	0.137
30.478	138.000	0.906	0.793	0.709	0.355	1.851	1.710	0.118	0.066
30.478	140.000	0.919	0.785	0.700	0.354	1.851	1.957	0.250	0.121
30.480	142.000	0.932	0.777	0.693	0.353	1.819	1.642	0.243	0.142
30.480	144.000	0.945	0.768	0.683	0.351	1.807	1.761	0.211	0.116
30.480	146.000	0.958	0.758	0.674	0.347	1.767	1.658	0.278	0.166
30.478	148.000	0.971	0.748	0.664	0.345	1.703	1.707	0.339	0.205
30.480	150.000	0.984	0.741	0.657	0.344	1.662	1.724	0.177	0.108
30.482	152.000	0.997	0.731	0.648	0.340	1.665	1.765	0.404	0.241
30.478	154.000	1.010	0.725	0.641	0.339	1.779	1.829	0.293	0.158
30.480	156.000	1.024	0.714	0.630	0.335	1.791	1.877	0.411	0.214
30.480	157.998	1.037	0.708	0.625	0.334	1.955	1.690	0.467	0.248
30.482	160.000	1.050	0.701	0.618	0.330	1.904	1.776	0.386	0.200
30.482	162.000	1.063	0.690	0.607	0.328	1.955	1.815	0.399	0.197
30.478	164.000	1.076	0.683	0.600	0.326	2.009	1.721	0.541	0.274

Survey Number 11									
Station 6 - Repeat Survey									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
30.482	37.700	0.247	1.313	1.153	0.629	2.700	1.970	-0.251	-0.083
30.476	38.000	0.249	1.311	1.152	0.626	2.909	2.153	-0.629	-0.177
30.480	40.000	0.262	1.297	1.147	0.606	2.287	1.964	-0.283	-0.111
30.482	42.000	0.276	1.283	1.140	0.588	2.985	2.107	-0.339	-0.095
30.482	44.000	0.289	1.267	1.131	0.572	2.177	2.018	-0.281	-0.113
30.478	46.000	0.302	1.250	1.119	0.556	7.597	2.065	-0.232	-0.026
30.480	48.000	0.315	1.238	1.114	0.541	4.071	1.998	-0.245	-0.053
30.480	50.000	0.328	1.217	1.096	0.530	8.457	2.031	0.131	0.013
30.480	52.000	0.341	1.207	1.093	0.512	4.268	1.875	0.095	0.021
30.480	54.000	0.354	1.192	1.081	0.502	1.949	1.858	0.108	0.053
30.480	56.000	0.367	1.181	1.073	0.492	2.596	1.864	0.168	0.061
30.482	58.000	0.381	1.168	1.064	0.483	2.241	1.831	0.101	0.043
30.482	60.000	0.394	1.152	1.049	0.474	6.395	1.987	-0.042	-0.006
30.482	62.000	0.407	1.143	1.043	0.467	3.455	1.841	0.214	0.059
30.480	64.000	0.420	1.128	1.030	0.461	5.697	2.022	0.102	0.016
30.482	66.000	0.433	1.115	1.019	0.453	6.246	1.868	0.034	0.005
30.480	68.000	0.446	1.103	1.008	0.446	5.094	1.931	0.493	0.088
30.478	70.000	0.459	1.090	0.998	0.439	3.763	1.991	0.281	0.066
30.480	72.000	0.472	1.082	0.989	0.437	2.357	1.960	0.263	0.100
30.482	74.000	0.486	1.071	0.981	0.430	2.333	1.925	0.372	0.146
30.482	76.000	0.499	1.056	0.966	0.426	2.689	1.862	0.258	0.091
30.482	78.000	0.512	1.042	0.954	0.419	2.789	1.890	0.017	0.006
30.480	80.000	0.525	1.035	0.947	0.417	1.899	1.762	0.130	0.069
30.480	82.000	0.538	1.025	0.938	0.413	2.589	1.894	0.168	0.061
30.478	84.002	0.551	1.017	0.934	0.402	2.149	1.811	0.115	0.052
30.482	86.002	0.564	1.009	0.927	0.400	2.370	1.783	0.093	0.039
30.480	88.000	0.577	0.997	0.915	0.396	1.795	1.860	0.145	0.077
30.480	90.000	0.591	0.989	0.907	0.393	3.064	1.726	0.363	0.121
30.478	92.000	0.604	0.980	0.898	0.392	2.448	1.802	0.254	0.101
30.482	94.000	0.617	0.972	0.890	0.391	2.455	1.816	0.294	0.116
30.476	96.000	0.630	0.964	0.882	0.388	2.831	1.902	0.182	0.060
30.480	98.000	0.643	0.956	0.874	0.387	2.590	1.790	0.273	0.104
30.482	100.000	0.656	0.950	0.867	0.386	2.132	1.700	0.242	0.117
30.480	102.000	0.669	0.942	0.860	0.385	2.596	1.738	0.533	0.208
30.480	104.000	0.682	0.934	0.852	0.384	2.999	1.744	0.218	0.073
30.478	106.000	0.696	0.927	0.844	0.383	2.260	1.693	0.338	0.155
30.480	108.000	0.709	0.922	0.838	0.383	3.238	1.784	0.145	0.044
30.480	110.000	0.722	0.914	0.832	0.379	2.329	1.877	0.407	0.164
30.482	112.000	0.735	0.908	0.824	0.381	2.226	1.813	0.265	0.116
30.480	114.000	0.748	0.899	0.816	0.378	2.078	1.819	0.212	0.099
30.480	116.000	0.761	0.890	0.807	0.375	2.918	1.852	0.191	0.062
30.480	118.000	0.774	0.881	0.798	0.375	2.215	1.850	0.333	0.143
30.482	120.000	0.787	0.869	0.787	0.370	2.485	1.845	0.182	0.070
30.480	122.000	0.801	0.859	0.777	0.367	2.060	1.827	0.361	0.169
30.480	124.002	0.814	0.852	0.768	0.368	2.170	1.788	0.255	0.116
30.480	126.000	0.827	0.844	0.760	0.366	2.027	1.774	0.231	0.113
30.478	128.000	0.840	0.829	0.745	0.364	6.091	1.746	-0.103	-0.017
30.480	130.000	0.853	0.823	0.739	0.362	4.605	1.687	0.021	0.005
30.480	132.000	0.866	0.819	0.735	0.361	2.291	1.657	0.299	0.139
30.480	134.000	0.879	0.811	0.727	0.360	3.211	1.624	0.092	0.031
30.478	136.000	0.892	0.801	0.716	0.359	4.451	1.640	0.131	0.032
30.478	138.000	0.906	0.793	0.708	0.357	4.515	1.611	0.190	0.046
30.480	140.000	0.919	0.786	0.701	0.355	3.183	1.622	0.011	0.004
30.480	142.000	0.932	0.777	0.692	0.353	2.905	1.663	0.304	0.111
30.478	144.000	0.945	0.768	0.683	0.352	1.956	1.696	0.321	0.170
30.480	146.000	0.958	0.761	0.676	0.349	1.913	1.667	0.246	0.136
30.480	148.000	0.971	0.751	0.666	0.347	2.197	1.802	0.231	0.103
30.478	150.000	0.984	0.743	0.658	0.344	1.812	1.668	0.163	0.095
30.480	152.000	0.997	0.734	0.650	0.342	1.815	1.765	0.335	0.184
30.478	154.000	1.010	0.725	0.641	0.339	1.862	1.773	0.392	0.209
30.480	156.000	1.024	0.718	0.633	0.338	1.925	1.783	0.441	0.226
30.480	158.000	1.037	0.708	0.625	0.334	2.064	1.720	0.487	0.242
30.478	160.000	1.050	0.700	0.616	0.332	2.035	1.753	0.548	0.271
30.482	162.000	1.063	0.690	0.607	0.330	2.034	1.836	0.560	0.264
30.480	164.000	1.076	0.682	0.599	0.327	2.110	1.808	0.619	0.286

Survey Number 12									
Station 7									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
60.960	51.800	0.340	0.889	0.862	0.218	41.103	1.791	1.197	0.029
60.962	52.000	0.341	1.022	0.999	0.216	32.063	2.038	-0.486	-0.013
60.960	54.000	0.354	1.165	1.144	0.221	11.320	1.723	-0.051	-0.005
60.960	56.000	0.367	1.167	1.145	0.224	5.254	1.670	0.083	0.017
60.962	58.000	0.381	1.145	1.122	0.228	8.618	1.882	-0.064	-0.007
60.962	60.000	0.394	1.139	1.116	0.231	3.116	1.785	0.217	0.069
60.958	61.992	0.407	1.121	1.097	0.231	7.159	1.690	0.126	0.018
60.960	64.000	0.420	1.114	1.089	0.236	3.594	1.724	0.066	0.019
60.960	66.000	0.433	1.100	1.074	0.240	3.510	1.791	0.200	0.056
60.960	68.000	0.446	1.087	1.060	0.242	3.948	1.779	0.145	0.036
60.962	70.000	0.459	1.074	1.045	0.244	5.828	1.787	0.163	0.027
60.960	72.000	0.472	1.061	1.032	0.245	5.228	1.908	0.173	0.030
60.960	74.000	0.486	1.052	1.023	0.249	4.217	1.865	0.226	0.050
60.960	76.000	0.499	1.038	1.008	0.251	4.941	1.975	0.373	0.067
60.960	78.000	0.512	1.031	1.000	0.251	2.292	1.868	0.118	0.048
60.958	80.000	0.525	1.011	0.979	0.251	4.515	1.956	0.452	0.090
60.960	82.000	0.538	1.003	0.971	0.253	3.924	1.864	0.234	0.056
60.960	84.000	0.551	0.993	0.960	0.254	4.548	1.840	0.457	0.096
60.960	86.002	0.564	0.979	0.945	0.252	4.386	1.763	0.349	0.079
60.960	88.000	0.577	0.973	0.940	0.251	2.936	1.644	0.249	0.091
60.960	90.000	0.591	0.964	0.931	0.252	3.400	1.725	0.064	0.019
60.958	92.000	0.604	0.957	0.923	0.254	2.396	1.737	0.069	0.029
60.960	94.000	0.617	0.946	0.912	0.251	3.623	1.812	0.057	0.015
60.960	95.998	0.630	0.938	0.903	0.254	2.431	1.779	0.139	0.056
60.960	98.000	0.643	0.929	0.894	0.256	3.318	1.719	0.261	0.080
60.958	100.000	0.656	0.922	0.886	0.255	2.570	1.775	0.310	0.119
60.960	102.000	0.669	0.909	0.872	0.256	4.920	1.773	0.413	0.083
60.960	103.998	0.682	0.905	0.868	0.255	2.303	1.813	0.205	0.086
60.960	106.000	0.696	0.895	0.858	0.254	3.901	1.830	0.210	0.052
60.960	108.000	0.709	0.888	0.851	0.255	2.491	1.811	0.461	0.179
60.960	110.000	0.722	0.882	0.845	0.254	2.378	1.911	0.298	0.115
60.960	112.002	0.735	0.872	0.835	0.252	4.087	1.677	0.199	0.051
60.962	114.000	0.748	0.869	0.832	0.250	2.822	1.811	0.319	0.109
60.962	116.000	0.761	0.864	0.827	0.250	2.963	1.719	0.376	0.129
60.958	118.000	0.774	0.857	0.820	0.250	2.864	1.900	0.327	0.105
60.960	120.000	0.787	0.851	0.814	0.248	2.960	1.803	0.371	0.122
60.962	122.000	0.801	0.844	0.806	0.248	2.299	1.874	0.355	0.145
60.960	124.000	0.814	0.836	0.799	0.246	2.594	1.861	0.511	0.185
60.960	126.000	0.827	0.827	0.790	0.245	4.041	1.843	0.297	0.070
60.962	128.000	0.840	0.820	0.782	0.245	3.242	1.847	0.334	0.098
60.958	130.000	0.853	0.811	0.774	0.241	2.278	1.859	0.519	0.215
60.958	132.000	0.866	0.800	0.764	0.238	2.125	1.782	0.297	0.137
60.960	134.000	0.879	0.791	0.755	0.236	2.887	1.867	0.478	0.155
60.960	136.000	0.892	0.784	0.748	0.233	2.110	1.781	0.310	0.145
60.960	138.000	0.906	0.776	0.741	0.229	2.549	1.740	0.305	0.121
60.960	140.000	0.919	0.771	0.736	0.229	2.176	1.681	0.367	0.176
60.960	142.000	0.932	0.761	0.727	0.225	2.356	1.629	0.359	0.164
60.962	144.000	0.945	0.755	0.721	0.222	2.059	1.621	0.309	0.163
60.960	146.000	0.958	0.748	0.715	0.220	2.001	1.615	0.253	0.137
60.960	148.000	0.971	0.739	0.707	0.216	2.099	1.705	0.257	0.126
60.960	150.000	0.984	0.731	0.698	0.214	2.747	1.565	0.242	0.099
60.960	152.002	0.997	0.723	0.691	0.211	2.204	1.710	0.274	0.127
60.962	154.000	1.010	0.713	0.682	0.207	2.810	1.668	0.338	0.126
60.960	156.000	1.024	0.706	0.675	0.204	1.818	1.702	0.365	0.207
60.960	158.000	1.037	0.698	0.669	0.200	1.966	1.789	0.298	0.149
60.960	160.000	1.050	0.690	0.662	0.195	1.806	1.981	0.500	0.245
60.960	162.000	1.063	0.682	0.654	0.192	1.854	1.771	0.224	0.120
60.962	164.000	1.076	0.671	0.645	0.186	2.000	1.877	0.528	0.246
60.962	166.000	1.089	0.663	0.638	0.181	2.004	1.859	0.563	0.265
60.960	168.000	1.102	0.653	0.628	0.179	1.939	1.939	0.564	0.263
60.962	170.000	1.115	0.647	0.624	0.173	1.998	1.802	0.553	0.269
60.960	172.000	1.129	0.637	0.615	0.167	2.156	1.770	0.583	0.268
60.960	174.000	1.142	0.627	0.605	0.164	2.458	1.759	0.601	0.244
60.960	176.000	1.155	0.620	0.599	0.159	2.323	1.655	0.482	0.220
60.958	178.000	1.168	0.610	0.591	0.154	2.466	1.641	0.661	0.286
60.962	178.700	1.173	0.607	0.588	0.153	2.314	1.669	0.641	0.291

Survey Number 13									
Station 7 - Repeat Survey with Yaw									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
60.960	60.000	0.394	1.129	1.105	0.234	6.263	1.758	0.0665	0.0106
60.960	59.000	0.387	1.134	1.110	0.234	7.527	1.721	0.2066	0.0279
60.960	58.000	0.381	1.142	1.119	0.231	6.496	1.615	0.4242	0.0708
60.960	57.000	0.374	1.147	1.123	0.231	7.838	1.752	-0.5139	-0.0656
60.960	56.000	0.367	1.149	1.126	0.228	9.162	1.756	-0.1826	-0.0199
60.960	55.000	0.361	1.145	1.122	0.226	12.259	1.704	-0.0334	-0.0028
60.960	54.000	0.354	1.134	1.111	0.224	15.615	1.944	-0.1200	-0.0069
60.960	52.998	0.348	1.102	1.080	0.220	21.190	1.647	-0.5100	-0.0256
60.960	51.996	0.341	0.968	0.942	0.221	32.848	1.872	-2.8476	-0.0812
60.960	50.986	0.335	0.760	0.729	0.217	36.975	1.719	-2.8050	-0.0773
60.960	50.000	0.328	0.472	0.419	0.218	22.765	1.705	-0.7044	-0.0318
60.960	49.000	0.322	0.414	0.355	0.212	15.050	1.817	-0.0051	-0.0003
60.960	47.998	0.315	0.391	0.329	0.211	12.898	1.735	-0.0373	-0.0029
60.960	46.996	0.308	0.374	0.310	0.210	12.205	1.855	1.0416	0.0806
60.960	45.996	0.302	0.366	0.301	0.208	12.253	2.060	0.8281	0.0575
60.960	44.998	0.295	0.364	0.302	0.204	12.046	1.715	-0.0251	-0.0021
60.960	44.000	0.289	0.350	0.287	0.201	12.189	1.613	0.7789	0.0694
60.960	42.998	0.282	0.352	0.290	0.198	11.430	1.582	-0.0038	-0.0004

Survey Number 14										
Station 7 Boundary Layer Survey										
x(mm)	y(mm)	d/c	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
60.470	41.942	0.013	0.275	0.350	0.242	0.253	11.946	9.609	0.527	0.008
60.394	42.178	0.015	0.277	0.315	0.229	0.217	10.445	2.231	-0.042	-0.003
60.318	42.420	0.017	0.278	0.358	0.287	0.213	12.544	2.041	-0.236	-0.016
60.240	42.654	0.018	0.280	0.366	0.296	0.215	12.508	1.688	0.524	0.043
60.164	42.896	0.020	0.281	0.370	0.299	0.218	12.381	1.806	0.147	0.011
60.088	43.130	0.022	0.283	0.379	0.308	0.221	12.560	1.811	0.135	0.010
60.012	43.370	0.024	0.285	0.381	0.311	0.221	11.905	1.771	-0.043	-0.004
59.934	43.610	0.026	0.286	0.379	0.307	0.222	12.443	1.901	-0.200	-0.015
59.858	43.844	0.028	0.288	0.385	0.313	0.224	12.254	1.826	1.035	0.081
59.782	44.086	0.030	0.289	0.387	0.315	0.224	12.282	1.823	0.386	0.030
59.706	44.320	0.032	0.291	0.379	0.306	0.225	12.339	1.788	-0.363	-0.029
59.630	44.562	0.034	0.292	0.390	0.318	0.226	12.886	1.867	-0.296	-0.021
59.552	44.796	0.036	0.294	0.384	0.309	0.227	12.445	1.853	0.021	0.002
59.478	45.038	0.038	0.296	0.385	0.310	0.229	12.567	1.927	-0.023	-0.002
59.400	45.274	0.040	0.297	0.382	0.306	0.229	12.735	1.945	0.880	0.062
59.322	45.514	0.042	0.299	0.384	0.306	0.231	12.458	1.896	0.585	0.043
59.246	45.750	0.044	0.300	0.376	0.295	0.233	12.596	1.816	0.299	0.023
59.170	45.990	0.046	0.302	0.384	0.304	0.234	12.603	1.878	0.383	0.028
59.094	46.224	0.048	0.303	0.381	0.300	0.236	12.668	2.016	0.115	0.008
59.016	46.466	0.050	0.305	0.379	0.296	0.237	12.297	1.886	0.559	0.042
58.940	46.700	0.052	0.306	0.380	0.295	0.239	12.751	1.997	0.423	0.029
58.862	46.944	0.054	0.308	0.374	0.286	0.241	12.122	1.803	0.161	0.013
58.788	47.176	0.056	0.310	0.380	0.293	0.243	12.730	1.940	0.296	0.021
58.710	47.418	0.058	0.311	0.375	0.285	0.244	12.512	1.925	-0.486	-0.035
58.634	47.654	0.060	0.313	0.379	0.290	0.243	12.625	1.826	0.303	0.023
58.558	47.894	0.062	0.314	0.383	0.295	0.244	12.897	1.921	0.053	0.004
58.482	48.130	0.064	0.316	0.377	0.288	0.244	13.004	1.836	-0.212	-0.015
58.406	48.370	0.066	0.317	0.382	0.295	0.243	12.870	1.789	0.357	0.027
58.328	48.606	0.068	0.319	0.369	0.276	0.245	12.449	1.911	-0.291	-0.021
58.252	48.846	0.070	0.321	0.371	0.280	0.242	12.510	1.805	0.902	0.070
58.174	49.082	0.072	0.322	0.368	0.276	0.243	12.630	1.841	0.784	0.059
58.100	49.320	0.074	0.324	0.366	0.274	0.244	12.511	1.797	-0.379	-0.029
58.022	49.558	0.076	0.325	0.370	0.278	0.244	12.967	1.827	0.761	0.056
57.946	49.798	0.078	0.327	0.372	0.278	0.247	12.527	1.945	-0.012	-0.001
57.870	50.032	0.080	0.328	0.372	0.278	0.248	13.192	1.986	0.430	0.029
57.792	50.274	0.082	0.330	0.380	0.287	0.249	13.457	1.841	-0.335	-0.024
57.716	50.510	0.083	0.331	0.399	0.308	0.254	14.485	1.949	0.173	0.011
57.640	50.750	0.085	0.333	0.395	0.301	0.256	14.931	1.842	0.840	0.053
57.562	50.986	0.087	0.335	0.400	0.308	0.255	16.599	2.077	-0.130	-0.007
57.486	51.226	0.089	0.336	0.397	0.304	0.255	16.303	1.854	0.544	0.031
57.410	51.462	0.091	0.338	0.406	0.314	0.257	17.370	1.946	0.647	0.033
57.334	51.704	0.093	0.339	0.419	0.330	0.258	20.602	1.887	0.201	0.009
57.256	51.936	0.095	0.341	0.424	0.335	0.260	20.365	1.826	-0.562	-0.026
57.180	52.178	0.097	0.342	0.442	0.357	0.261	25.152	2.085	0.967	0.032
57.104	52.412	0.099	0.344	0.477	0.398	0.264	28.720	1.985	-1.313	-0.040
57.030	52.652	0.101	0.345	0.455	0.370	0.264	26.006	2.285	-0.692	-0.020
56.952	52.892	0.103	0.347	0.521	0.449	0.264	33.499	1.834	-1.340	-0.038
56.874	53.130	0.105	0.349	0.530	0.459	0.265	35.067	1.952	-0.742	-0.019
56.798	53.366	0.107	0.350	0.596	0.533	0.265	38.184	1.836	0.432	0.011
56.722	53.606	0.109	0.352	0.595	0.532	0.266	38.585	1.963	-2.406	-0.055

Survey Number 15										
Station 7- Repeat Boundary Layer Survey										
x(mm)	y(mm)	d/c	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
60.470	41.942	0.013	0.275	0.383	0.332	0.191	15.336	3.145	0.033	0.001
60.318	42.420	0.017	0.278	0.373	0.310	0.208	12.385	2.037	-0.047	-0.003
60.164	42.894	0.020	0.281	0.381	0.316	0.213	12.291	1.598	0.135	0.012
60.012	43.370	0.024	0.285	0.383	0.314	0.219	12.395	1.703	0.068	0.006
59.858	43.848	0.028	0.288	0.386	0.315	0.223	12.388	1.587	-0.191	-0.017
59.706	44.322	0.032	0.291	0.394	0.323	0.224	12.366	1.663	0.519	0.044
59.552	44.798	0.036	0.294	0.391	0.318	0.227	12.323	1.662	-0.098	-0.008
59.400	45.274	0.040	0.297	0.393	0.318	0.230	12.384	1.793	0.073	0.006
59.246	45.750	0.044	0.300	0.392	0.315	0.234	12.374	1.779	0.276	0.022
59.096	46.226	0.048	0.303	0.387	0.306	0.238	12.280	1.746	0.537	0.044
58.940	46.702	0.052	0.306	0.394	0.313	0.239	12.233	1.779	0.545	0.044
58.790	47.178	0.056	0.310	0.402	0.321	0.242	12.467	1.707	-0.406	-0.033
58.634	47.654	0.060	0.313	0.401	0.318	0.244	12.390	1.854	-0.158	-0.012
58.482	48.130	0.064	0.316	0.406	0.322	0.248	13.082	1.788	0.304	0.023
58.328	48.606	0.068	0.319	0.404	0.319	0.248	12.918	1.809	-0.125	-0.009
58.178	49.082	0.072	0.322	0.404	0.318	0.250	13.148	1.839	-0.016	-0.001
58.022	49.560	0.076	0.325	0.418	0.333	0.253	14.258	1.871	-0.061	-0.004
57.870	50.036	0.080	0.328	0.419	0.332	0.256	14.706	1.864	-0.150	-0.010
57.716	50.510	0.083	0.331	0.452	0.372	0.256	20.624	1.806	-0.574	-0.027
57.564	50.986	0.087	0.335	0.502	0.430	0.259	26.085	1.936	-1.257	-0.044
57.410	51.464	0.091	0.338	0.509	0.437	0.260	27.236	1.818	-0.477	-0.017
57.258	51.940	0.095	0.341	0.524	0.452	0.264	30.137	1.733	-3.326	-0.111
57.104	52.416	0.099	0.344	0.644	0.587	0.265	37.433	1.741	-0.149	-0.004
56.952	52.892	0.103	0.347	0.709	0.656	0.267	39.697	1.829	0.017	0.000
56.798	53.366	0.107	0.350	0.730	0.679	0.270	39.990	1.749	-2.020	-0.050
56.646	53.844	0.111	0.353	0.822	0.777	0.270	40.442	1.723	-1.189	-0.030
56.492	54.320	0.115	0.356	0.907	0.866	0.271	38.003	1.756	-2.070	-0.054
56.340	54.796	0.119	0.360	0.913	0.871	0.274	37.882	1.744	0.129	0.003
56.184	55.270	0.123	0.363	0.997	0.958	0.275	33.431	1.794	-1.391	-0.041
56.034	55.748	0.127	0.366	1.011	0.972	0.278	31.966	1.735	0.422	0.013

Survey Number 16									
Station 8									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
91.440	50.500	0.331	1.040	1.040	-0.004	2.024	1.441	0.172	0.102
91.440	53.000	0.348	1.034	1.034	0.010	2.274	1.464	0.189	0.098
91.440	57.000	0.374	1.020	1.020	0.030	2.008	1.488	0.172	0.100
91.440	61.000	0.400	1.008	1.007	0.049	1.883	1.529	0.205	0.123
91.438	65.000	0.427	0.995	0.993	0.068	1.911	1.450	0.163	0.102
91.440	69.000	0.453	0.982	0.979	0.080	2.347	1.568	0.227	0.107
91.440	73.020	0.479	0.971	0.967	0.093	2.025	1.594	0.367	0.197
91.438	77.000	0.505	0.959	0.954	0.105	1.974	1.698	0.276	0.142
91.438	81.000	0.531	0.947	0.940	0.115	1.922	1.734	0.333	0.173
91.438	85.000	0.558	0.933	0.925	0.124	1.892	1.728	0.306	0.162
91.440	89.000	0.584	0.922	0.913	0.131	1.796	1.710	0.386	0.218
91.440	93.000	0.610	0.908	0.898	0.136	1.930	1.673	0.264	0.142
91.440	97.000	0.636	0.897	0.886	0.141	1.866	1.595	0.282	0.164
91.438	101.000	0.663	0.886	0.874	0.142	1.793	1.491	0.177	0.115
91.440	105.000	0.689	0.875	0.863	0.145	1.762	1.520	0.381	0.246
91.440	109.000	0.715	0.865	0.852	0.148	1.856	1.569	0.323	0.192
91.440	113.000	0.741	0.852	0.839	0.148	1.943	1.540	0.304	0.176
91.440	117.000	0.768	0.841	0.828	0.149	1.910	1.576	0.368	0.212
91.438	121.000	0.794	0.836	0.824	0.145	2.021	1.561	0.444	0.244
91.440	125.000	0.820	0.826	0.814	0.144	1.905	1.653	0.363	0.199
91.436	129.000	0.846	0.815	0.803	0.140	2.318	1.704	0.397	0.174
91.436	133.000	0.873	0.806	0.794	0.137	1.906	1.786	0.421	0.214
91.438	137.000	0.899	0.794	0.783	0.133	1.860	1.704	0.310	0.170
91.436	141.000	0.925	0.778	0.768	0.129	1.768	1.743	0.492	0.276
91.440	145.000	0.951	0.767	0.758	0.121	2.037	1.696	0.430	0.215
91.440	149.000	0.978	0.756	0.747	0.116	1.856	1.656	0.259	0.146
91.440	153.000	1.004	0.744	0.736	0.108	1.763	1.616	0.371	0.225
91.438	157.000	1.030	0.735	0.728	0.099	1.761	1.693	0.231	0.134
91.438	161.000	1.056	0.722	0.716	0.090	1.762	1.642	0.406	0.243
91.438	165.000	1.083	0.712	0.708	0.079	1.822	1.710	0.526	0.292
91.440	169.000	1.109	0.697	0.694	0.070	1.909	1.788	0.531	0.269
91.438	173.000	1.135	0.681	0.679	0.057	2.114	1.814	0.591	0.267
91.440	177.000	1.161	0.667	0.666	0.044	1.802	2.012	0.550	0.263
91.440	179.000	1.175	0.660	0.659	0.037	2.015	1.772	0.595	0.288

Survey Number 17									
Station 8 Boundary Layer Survey									
x	y	d/c	W/Vref	U/Vref	V/V[illegible]	Tu	Tv	Re stress	Cuv
91.438	189.500	0.005	0.538	0.538	0.0[illegible]	5.625	3.543	5.017	0.432
91.446	189.000	0.009	0.564	0.563	0.01[illegible]	5.283	4.272	3.660	0.278
91.456	188.500	0.013	0.585	0.585	0.011	4.755	3.286	3.406	0.374
91.466	188.000	0.017	0.606	0.606	0.014	4.269	2.943	2.461	0.336
91.472	187.500	0.021	0.622	0.622	0.014	3.516	2.595	1.370	0.258
91.478	187.000	0.024	0.634	0.634	0.016	2.658	1.838	0.785	0.276
91.486	186.500	0.028	0.639	0.639	0.014	2.268	1.841	0.659	0.271
91.494	186.000	0.032	0.642	0.642	0.017	1.935	1.727	0.585	0.301
91.502	185.500	0.036	0.644	0.644	0.019	1.939	1.678	0.616	0.325
91.510	185.000	0.040	0.647	0.647	0.020	1.854	1.632	0.435	0.247
91.518	184.500	0.044	0.649	0.649	0.021	1.878	1.627	0.593	0.333
91.526	184.000	0.048	0.651	0.650	0.024	1.765	1.700	0.523	0.299
91.534	183.500	0.052	0.652	0.651	0.025	1.867	1.699	0.549	0.297
91.540	183.000	0.056	0.654	0.653	0.027	1.817	1.732	0.639	0.349
91.550	182.500	0.060	0.656	0.655	0.029	1.781	1.755	0.591	0.325
91.558	182.002	0.064	0.658	0.657	0.030	1.902	1.789	0.614	0.310
91.564	181.502	0.068	0.659	0.658	0.031	1.832	1.823	0.619	0.318
91.572	181.002	0.072	0.661	0.660	0.033	1.822	1.702	0.581	0.322
91.582	180.502	0.076	0.663	0.662	0.034	1.769	1.768	0.631	0.346
91.590	180.002	0.080	0.663	0.662	0.035	1.905	1.755	0.631	0.324
91.598	179.502	0.084	0.666	0.665	0.038	1.809	1.811	0.632	0.331

Survey Number 18									
Station 9									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
115.822	50.270	0.330	0.932	0.931	-0.041	1.880	1.459	0.152	0.096
115.824	53.000	0.348	0.930	0.930	-0.029	1.856	1.397	0.107	0.072
115.822	57.000	0.374	0.925	0.924	-0.012	1.813	1.352	0.070	0.050
115.824	61.002	0.400	0.920	0.920	0.002	1.780	1.379	0.127	0.089
115.824	65.000	0.427	0.915	0.915	0.015	1.923	1.483	0.276	0.168
115.822	69.002	0.453	0.912	0.912	0.028	1.931	1.489	0.318	0.191
115.822	73.000	0.479	0.908	0.907	0.041	2.141	1.495	0.226	0.122
115.824	77.000	0.505	0.906	0.905	0.048	1.950	1.614	0.296	0.163
115.822	81.000	0.531	0.902	0.901	0.057	1.922	1.663	0.377	0.204
115.822	85.000	0.558	0.895	0.893	0.065	1.989	1.703	0.462	0.236
115.822	89.000	0.584	0.889	0.886	0.074	2.191	1.699	0.430	0.200
115.822	93.000	0.610	0.880	0.876	0.078	1.939	1.588	0.308	0.173
115.822	97.000	0.636	0.874	0.870	0.084	1.843	1.529	0.230	0.141
115.822	101.000	0.663	0.867	0.863	0.087	2.057	1.560	0.310	0.167
115.822	105.000	0.689	0.858	0.853	0.091	1.819	1.565	0.286	0.174
115.822	109.000	0.715	0.853	0.847	0.094	1.776	1.569	0.243	0.151
115.822	113.000	0.741	0.845	0.840	0.095	1.764	1.556	0.246	0.155
115.820	117.000	0.768	0.839	0.833	0.096	1.777	1.614	0.445	0.269
115.822	121.000	0.794	0.834	0.829	0.093	1.844	1.673	0.389	0.218
115.820	125.000	0.820	0.829	0.824	0.094	1.982	1.736	0.425	0.214
115.824	129.000	0.846	0.824	0.819	0.091	1.967	1.745	0.468	0.236
115.822	133.000	0.873	0.823	0.818	0.090	1.888	1.797	0.580	0.296
115.824	137.000	0.899	0.814	0.809	0.086	1.914	1.760	0.506	0.260
115.824	141.000	0.925	0.808	0.803	0.083	1.840	1.797	0.495	0.259
115.824	145.000	0.951	0.798	0.794	0.076	1.843	1.755	0.475	0.254
115.824	149.000	0.978	0.793	0.790	0.071	1.810	1.758	0.416	0.227
115.822	153.000	1.004	0.785	0.782	0.062	1.867	1.621	0.270	0.154
115.822	157.000	1.030	0.781	0.780	0.053	1.824	1.711	0.412	0.228
115.822	161.000	1.056	0.781	0.780	0.041	1.808	1.708	0.360	0.202
115.822	165.000	1.083	0.779	0.779	0.031	1.790	1.809	0.414	0.222
115.822	169.000	1.109	0.777	0.777	0.015	1.758	1.835	0.445	0.239
115.822	173.000	1.135	0.775	0.775	-0.001	1.830	1.879	0.417	0.210
115.826	177.000	1.161	0.777	0.777	-0.021	1.927	1.950	0.513	0.236
115.824	178.100	1.169	0.776	0.776	-0.027	1.921	1.882	0.625	0.299

Survey Number 19										
Station 9 Boundary Layer Survey										
x	y	d/c	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
115.878	39.784	0.006	0.620	0.618	-0.046	8.833	4.642	[illegible]	-0.186
115.910	40.280	0.009	0.702	0.701	0.040	9.979	11.533	[illegible]	0.024
115.946	40.780	0.013	0.755	0.755	-0.027	9.917	5.961	[illegible]	-0.094
115.980	41.278	0.017	0.816	0.815	-0.034	9.210	5.964	-3.100	-0.097
116.014	41.776	0.021	0.855	0.854	-0.045	8.450	5.596	-4.154	-0.152
116.046	42.276	0.025	0.892	0.891	-0.055	6.881	4.945	-1.533	-0.078
116.082	42.774	0.029	0.921	0.919	-0.066	5.011	4.164	-0.373	-0.031
116.114	43.272	0.033	0.938	0.936	-0.071	3.464	3.184	-0.367	-0.057
116.148	43.770	0.037	0.945	0.942	-0.073	2.575	2.693	-0.085	-0.021
116.182	44.268	0.041	0.946	0.943	-0.075	2.223	1.929	0.129	0.052
116.216	44.768	0.045	0.944	0.941	-0.073	1.949	2.051	0.100	0.043
116.250	45.266	0.049	0.944	0.941	-0.072	1.981	1.367	0.040	0.026
116.284	45.764	0.053	0.943	0.940	-0.070	1.877	1.310	0.099	0.070
116.318	46.262	0.057	0.940	0.938	-0.069	1.820	1.361	0.104	0.072
116.350	46.762	0.061	0.937	0.934	-0.065	1.798	1.274	0.085	0.064
116.384	47.260	0.065	0.939	0.937	-0.062	1.832	1.764	0.149	0.079
116.418	47.758	0.068	0.937	0.935	-0.061	1.799	1.497	0.144	0.092
116.452	48.256	0.072	0.934	0.932	-0.058	1.831	1.496	0.152	0.096
116.486	48.756	0.076	0.933	0.932	-0.055	1.775	1.380	0.048	0.034
116.518	49.254	0.080	0.934	0.932	-0.054	1.833	1.663	0.173	0.098
116.554	49.752	0.084	0.931	0.929	-0.051	1.830	2.030	0.149	0.069
116.586	50.250	0.088	0.929	0.928	-0.049	1.822	1.543	0.150	0.092
116.624	50.750	0.092	0.929	0.928	-0.046	1.808	1.523	0.098	0.062
116.654	51.248	0.096	0.928	0.927	-0.043	2.015	1.542	0.119	0.066
116.688	51.746	0.100	0.927	0.926	-0.041	1.748	1.388	0.159	0.113

Survey Number 20									
Station 10									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
121.920	48.498	0.318	0.912	0.910	-0.056	2.001	1.588	0.174	0.095
121.920	50.000	0.328	0.910	0.909	-0.048	2.009	1.512	0.179	0.102
121.920	54.000	0.354	0.906	0.905	-0.030	1.825	1.435	0.183	0.121
121.920	58.000	0.381	0.903	0.903	-0.014	1.824	1.381	0.184	0.126
121.920	62.000	0.407	0.901	0.901	0.000	1.800	1.388	0.185	0.128
121.920	66.000	0.433	0.900	0.900	0.012	1.817	1.450	0.269	0.177
121.920	70.000	0.459	0.898	0.897	0.025	1.978	1.513	0.276	0.160
121.920	74.000	0.486	0.895	0.894	0.034	2.115	1.504	0.257	0.140
121.920	78.000	0.512	0.895	0.894	0.046	2.034	1.500	0.233	0.132
121.920	82.000	0.538	0.890	0.888	0.055	2.048	1.538	0.324	0.178
121.920	86.000	0.564	0.886	0.884	0.063	1.987	1.606	0.416	0.226
121.918	90.000	0.591	0.879	0.876	0.069	1.981	1.594	0.454	0.249
121.918	94.002	0.617	0.874	0.870	0.074	1.996	1.702	0.423	0.215
121.920	98.000	0.643	0.867	0.863	0.078	1.818	1.606	0.330	0.196
121.920	102.000	0.669	0.861	0.857	0.080	1.830	1.705	0.434	0.241
121.918	106.000	0.696	0.853	0.849	0.082	1.914	1.641	0.350	0.193
121.918	110.000	0.722	0.849	0.845	0.084	1.840	1.552	0.225	0.136
121.918	114.000	0.748	0.844	0.840	0.087	1.840	1.596	0.303	0.179
121.916	118.000	0.774	0.838	0.833	0.086	1.978	1.705	0.473	0.243
121.918	122.000	0.801	0.835	0.831	0.087	2.015	1.764	0.559	0.272
121.918	126.000	0.827	0.831	0.827	0.087	1.965	1.800	0.528	0.258
121.920	130.000	0.853	0.826	0.822	0.083	2.026	1.767	0.532	0.257
121.920	134.000	0.879	0.822	0.818	0.081	2.088	1.795	0.669	0.309
121.920	138.000	0.906	0.818	0.814	0.078	1.820	1.853	0.476	0.245
121.920	142.000	0.932	0.813	0.809	0.074	1.838	1.777	0.577	0.306
121.920	146.000	0.958	0.806	0.803	0.069	1.826	1.733	0.444	0.243
121.920	150.000	0.984	0.801	0.799	0.063	1.807	1.744	0.399	0.219
121.920	154.000	1.010	0.797	0.795	0.056	1.828	1.746	0.494	0.268
121.918	158.000	1.037	0.796	0.795	0.046	1.713	1.758	0.418	0.240
121.918	162.000	1.063	0.797	0.796	0.035	1.759	1.627	0.351	0.212
121.918	166.000	1.089	0.795	0.795	0.026	1.716	1.779	0.348	0.197
121.918	170.000	1.115	0.797	0.797	0.014	1.742	1.903	0.512	0.267
121.918	174.000	1.142	0.801	0.801	0.003	1.803	1.809	0.506	0.269
121.920	176.000	1.155	0.806	0.806	-0.007	1.834	1.898	0.491	0.244

Survey Number 21									
Station 11									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
128.014	43.120	0.283	0.871	0.866	-0.088	2.953	2.101	-0.019	-0.005
128.016	44.000	0.289	0.877	0.873	-0.085	2.643	1.722	0.014	0.005
128.016	48.000	0.315	0.885	0.883	-0.061	2.053	1.331	0.068	0.044
128.016	52.000	0.341	0.889	0.888	-0.040	2.173	1.282	0.029	0.018
128.016	56.000	0.367	0.890	0.890	-0.023	1.884	1.300	0.066	0.047
128.016	60.000	0.394	0.892	0.892	-0.009	1.883	1.389	0.203	0.136
128.014	64.000	0.420	0.890	0.890	0.004	1.872	1.417	0.172	0.114
128.014	68.000	0.446	0.889	0.889	0.017	2.102	1.451	0.347	0.199
128.014	72.000	0.472	0.890	0.889	0.029	2.291	1.491	0.396	0.203
128.014	76.000	0.499	0.890	0.889	0.037	2.065	1.494	0.377	0.214
128.014	80.000	0.525	0.890	0.889	0.044	2.066	1.612	0.437	0.229
128.014	84.000	0.551	0.884	0.883	0.051	1.985	1.553	0.319	0.181
128.016	88.000	0.577	0.878	0.876	0.058	2.410	1.671	0.497	0.216
128.016	92.000	0.604	0.874	0.871	0.063	1.969	1.636	0.428	0.233
128.014	96.000	0.630	0.868	0.865	0.068	1.998	1.663	0.378	0.199
128.014	100.000	0.656	0.862	0.859	0.070	1.807	1.533	0.258	0.163
128.016	104.000	0.682	0.857	0.853	0.074	1.829	1.511	0.271	0.171
128.016	108.000	0.709	0.854	0.851	0.078	1.840	1.645	0.350	0.202
128.016	112.000	0.735	0.848	0.845	0.079	1.821	1.597	0.371	0.223
128.016	116.000	0.761	0.843	0.840	0.080	1.854	1.657	0.328	0.187
128.016	120.000	0.787	0.839	0.836	0.081	1.911	1.718	0.473	0.252
128.016	124.000	0.814	0.837	0.833	0.080	1.818	1.678	0.489	0.280
128.014	128.000	0.840	0.833	0.829	0.081	2.001	1.733	0.590	0.298
128.016	132.000	0.866	0.829	0.825	0.076	1.953	1.761	0.651	0.331
128.016	136.000	0.892	0.827	0.824	0.067	1.829	1.804	0.549	0.291
128.016	140.000	0.919	0.823	0.820	0.065	1.834	1.787	0.469	0.251
128.016	144.000	0.945	0.817	0.814	0.061	1.786	1.685	0.397	0.231
128.016	148.000	0.971	0.813	0.811	0.055	1.740	1.687	0.397	0.237
128.016	152.000	0.997	0.813	0.811	0.050	1.717	1.625	0.323	0.203
128.016	156.000	1.024	0.810	0.809	0.044	1.725	1.677	0.357	0.216
128.016	160.000	1.050	0.808	0.807	0.037	1.677	1.710	0.356	0.217
128.014	164.000	1.076	0.809	0.808	0.029	1.907	1.726	0.419	0.222
128.016	168.000	1.102	0.811	0.811	0.021	1.653	1.826	0.413	0.239
128.014	172.000	1.129	0.815	0.815	0.012	2.420	1.781	0.403	0.164
128.014	176.000	1.155	0.822	0.822	0.007	2.314	1.910	0.413	0.163
128.014	180.000	1.181	0.837	0.837	0.003	2.446	1.865	0.312	0.120
128.014	182.100	1.195	0.849	0.849	0.005	2.417	1.844	0.340	0.133

Survey Number 22									
Station 11 Wake Survey #1									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
128.014	26.002	0.171	0.822	0.822	0.007	2.195	2.016	0.539	0.216
128.016	26.500	0.174	0.824	0.824	0.007	2.453	1.966	0.639	0.235
128.016	27.016	0.177	0.827	0.827	0.006	1.913	2.005	0.422	0.195
128.016	27.500	0.180	0.825	0.825	0.008	2.872	2.014	0.466	0.143
128.014	28.000	0.184	0.829	0.829	0.008	2.537	1.900	0.297	0.109
128.014	28.500	0.187	0.830	0.830	0.007	2.038	1.942	0.473	0.212
128.014	29.000	0.190	0.832	0.832	0.008	2.666	1.972	0.580	0.196
128.014	29.500	0.194	0.834	0.834	0.011	2.164	1.893	0.408	0.177
128.014	30.000	0.197	0.835	0.835	0.010	2.140	2.031	0.253	0.103
128.014	30.500	0.200	0.836	0.835	0.014	2.707	2.052	0.264	0.084
128.014	31.000	0.203	0.835	0.835	0.017	2.358	2.073	0.398	0.144
128.014	31.500	0.207	0.832	0.832	0.017	3.420	2.516	0.755	0.156
128.014	32.000	0.210	0.825	0.825	0.020	4.034	2.749	1.023	0.164
128.012	32.498	0.213	0.819	0.819	0.029	4.375	3.094	0.642	0.084
128.014	33.000	0.217	0.802	0.801	0.033	5.081	3.807	0.708	0.065
128.016	33.500	0.220	0.781	0.780	0.041	6.012	4.732	2.049	0.128
128.016	34.000	0.223	0.741	0.739	0.052	8.316	5.930	0.266	0.010
128.016	34.500	0.226	0.679	0.675	0.075	11.290	6.621	1.201	0.029
128.016	35.000	0.230	0.579	0.567	0.116	15.483	8.500	13.910	0.188
128.016	35.500	0.233	0.392	0.370	0.130	18.403	12.604	29.490	0.226
128.016	36.000	0.236	0.229	0.198	0.115	16.325	15.002	35.414	0.257
128.014	36.500	0.240	0.141	0.123	0.069	12.304	14.766	11.082	0.108
128.014	37.000	0.243	0.164	0.163	0.019	14.659	13.003	-9.840	-0.092
128.014	37.500	0.246	0.285	0.283	-0.028	17.208	9.683	-16.922	-0.180
128.012	38.000	0.249	0.429	0.426	-0.047	14.416	8.235	-11.177	-0.167
128.012	38.500	0.253	0.523	0.519	-0.064	11.679	6.455	-1.690	-0.040
128.012	39.000	0.256	0.597	0.593	-0.064	9.620	5.459	-2.852	-0.096
128.014	39.500	0.259	0.638	0.635	-0.061	9.071	5.028	-2.122	-0.083
128.014	40.000	0.262	0.688	0.685	-0.067	8.314	4.520	-1.058	-0.050
128.012	40.500	0.266	0.717	0.714	-0.065	7.876	4.500	-2.248	-0.113
128.014	41.000	0.269	0.767	0.764	-0.068	7.499	4.154	-2.141	-0.122
128.014	41.500	0.272	0.796	0.793	-0.070	6.585	4.079	-1.643	-0.109
128.012	42.000	0.276	0.825	0.821	-0.078	5.309	3.243	-1.346	-0.139
128.012	42.500	0.279	0.844	0.840	-0.082	4.194	2.904	-0.573	-0.084
128.014	43.000	0.282	0.858	0.854	-0.082	3.111	2.180	0.034	0.009
128.014	43.500	0.285	0.862	0.858	-0.082	2.761	1.678	0.019	0.007
128.016	44.000	0.289	0.867	0.863	-0.081	2.364	1.407	0.045	0.024
128.014	44.500	0.292	0.868	0.865	-0.078	2.060	1.200	0.145	0.104
128.014	45.000	0.295	0.872	0.869	-0.075	2.328	1.137	0.112	0.075
128.014	45.500	0.299	0.873	0.870	-0.074	2.037	1.090	0.051	0.041
128.014	46.000	0.302	0.873	0.871	-0.070	2.043	1.154	0.092	0.069
128.016	46.500	0.305	0.873	0.870	-0.067	1.998	1.139	0.099	0.077
128.014	47.000	0.308	0.877	0.875	-0.064	2.264	1.185	0.115	0.076
128.014	47.500	0.312	0.877	0.874	-0.061	2.064	1.245	0.150	0.104
128.014	48.000	0.315	0.877	0.875	-0.059	1.944	1.272	0.086	0.062
128.014	48.500	0.318	0.877	0.875	-0.055	2.746	1.321	0.122	0.060
128.016	49.000	0.322	0.878	0.876	-0.053	1.995	1.289	0.149	0.103
128.016	49.500	0.325	0.878	0.876	-0.050	2.038	1.357	0.171	0.110
128.016	50.000	0.328	0.878	0.877	-0.049	1.972	1.341	0.119	0.080
128.016	50.500	0.331	0.878	0.877	-0.045	2.166	1.259	0.037	0.024
128.016	51.000	0.335	0.878	0.877	-0.042	2.234	1.274	0.037	0.023
128.014	51.502	0.338	0.880	0.879	-0.040	1.921	1.307	0.195	0.138
128.014	52.000	0.341	0.880	0.879	-0.037	1.923	1.289	0.148	0.106

Survey Number 23									
Station 11 Wake Survey #2									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
128.014	35.000	0.230	0.582	0.570	0.115	15.606	9.118	5.411	0.067
128.016	35.100	0.230	0.550	0.536	0.122	16.831	9.720	6.524	0.070
128.016	35.200	0.231	0.518	0.502	0.126	17.952	10.315	15.175	0.144
128.016	35.300	0.232	0.486	0.468	0.131	18.061	10.745	17.394	0.157
128.014	35.402	0.232	0.457	0.434	0.141	18.358	11.033	20.368	0.176
128.014	35.500	0.233	0.417	0.392	0.141	18.474	12.125	26.948	0.211
128.016	35.600	0.234	0.381	0.356	0.136	18.553	12.711	29.389	0.219
128.014	35.700	0.234	0.339	0.313	0.130	17.543	13.931	28.616	0.205
128.014	35.800	0.235	0.300	0.269	0.133	17.634	14.100	36.397	0.257
128.014	35.900	0.236	0.267	0.236	0.126	17.333	14.703	37.388	0.257
128.014	36.002	0.236	0.235	0.206	0.112	15.939	14.556	23.975	0.181
128.014	36.100	0.237	0.195	0.168	0.100	15.200	15.190	31.528	0.239
128.014	36.200	0.238	0.189	0.163	0.096	14.384	15.180	26.412	0.212
128.016	36.300	0.238	0.173	0.148	0.089	13.859	15.886	23.827	0.190
128.014	36.402	0.239	0.153	0.131	0.079	12.739	15.594	21.729	0.192
128.016	36.500	0.240	0.142	0.126	0.066	12.689	14.749	15.659	0.147
128.016	36.602	0.240	0.136	0.127	0.049	13.119	14.740	7.949	0.072
128.014	36.700	0.241	0.132	0.126	0.039	13.520	14.028	4.670	0.043
128.014	36.800	0.241	0.142	0.139	0.027	13.987	13.791	-0.179	-0.002
128.016	36.900	0.242	0.152	0.149	0.028	14.250	13.856	-3.557	-0.032
128.014	37.002	0.243	0.166	0.166	0.014	14.254	13.103	-7.835	-0.074
128.014	37.102	0.243	0.191	0.190	0.011	16.382	12.638	-8.678	-0.074
128.014	37.200	0.244	0.209	0.209	-0.003	16.556	12.053	-14.527	-0.128
128.016	37.300	0.245	0.240	0.240	-0.012	16.378	12.175	-24.577	-0.216
128.018	37.400	0.245	0.272	0.271	-0.017	16.721	11.124	-14.995	-0.141
128.016	37.500	0.246	0.290	0.289	-0.026	16.517	10.798	-12.789	-0.126
128.014	37.602	0.247	0.307	0.305	-0.028	17.510	10.844	-22.427	-0.207
128.014	37.700	0.247	0.337	0.335	-0.032	16.913	9.966	-15.061	-0.157
128.016	37.800	0.248	0.363	0.361	-0.039	16.278	9.096	-12.870	-0.152
128.014	37.900	0.249	0.392	0.389	-0.045	15.440	8.819	-12.536	-0.161
128.014	38.002	0.249	0.427	0.424	-0.050	14.681	8.343	-8.064	-0.115

Survey Number 24									
Station 12									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
134.110	34.980	0.230	0.676	0.668	0.099	12.161	7.283	0.807	0.016
134.110	41.330	0.271	0.602	0.601	-0.024	13.382	7.082	-9.848	-0.183
134.110	47.680	0.313	0.861	0.860	-0.038	2.492	1.427	0.144	0.071
134.110	54.030	0.355	0.866	0.866	-0.016	2.283	1.285	0.080	0.048
134.110	60.380	0.396	0.870	0.870	0.003	2.196	1.321	0.113	0.069
134.110	66.730	0.438	0.870	0.870	0.020	2.170	1.457	0.157	0.088
134.110	73.080	0.480	0.869	0.868	0.033	2.051	1.475	0.337	0.197
134.110	79.430	0.521	0.868	0.866	0.045	2.220	1.598	0.408	0.203
134.110	85.780	0.563	0.861	0.860	0.054	2.062	1.597	0.429	0.230
134.110	92.130	0.605	0.856	0.854	0.058	1.925	1.571	0.284	0.165
134.110	98.480	0.646	0.852	0.850	0.063	1.825	1.483	0.191	0.124
134.110	104.830	0.688	0.847	0.844	0.069	1.726	1.504	0.160	0.108
134.110	111.180	0.730	0.841	0.837	0.076	1.694	1.634	0.254	0.162
134.110	117.530	0.771	0.833	0.830	0.075	2.028	1.653	0.393	0.206
134.112	123.880	0.813	0.829	0.826	0.074	1.918	1.738	0.519	0.274
134.112	130.230	0.855	0.825	0.822	0.071	1.902	1.757	0.482	0.254
134.112	136.580	0.896	0.821	0.818	0.070	1.884	1.807	0.503	0.260
134.112	142.930	0.938	0.816	0.814	0.064	1.781	1.816	0.528	0.287
134.112	149.280	0.980	0.810	0.808	0.056	1.686	1.714	0.402	0.245
134.112	155.630	1.021	0.804	0.803	0.045	1.778	1.706	0.396	0.230
134.110	161.980	1.063	0.806	0.805	0.040	1.644	1.706	0.299	0.188
134.110	168.330	1.105	0.808	0.808	0.029	1.647	1.739	0.339	0.209
134.112	174.680	1.146	0.816	0.816	0.018	1.750	1.805	0.328	0.183
134.112	181.030	1.188	0.826	0.826	0.021	1.763	1.936	0.258	0.133
134.112	187.380	1.230	0.661	0.655	0.091	11.459	6.977	5.720	0.126
134.112	193.730	1.271	0.742	0.741	-0.041	8.316	5.912	-3.988	-0.143
134.112	200.080	1.313	0.861	0.860	-0.043	1.923	1.326	0.019	0.013

Survey Number 25									
Station 12 Wake Survey									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
134.110	25.000	0.164	0.828	0.827	0.029	1.796	1.936	0.490	0.248
134.110	25.500	0.167	0.829	0.828	0.027	1.762	1.916	0.240	0.125
134.110	25.998	0.171	0.830	0.829	0.029	1.791	2.036	0.443	0.214
134.110	26.500	0.174	0.831	0.830	0.030	1.795	2.353	0.443	0.185
134.110	27.000	0.177	0.831	0.831	0.029	1.729	1.986	0.382	0.196
134.110	27.500	0.180	0.832	0.832	0.030	2.327	1.998	0.428	0.162
134.110	27.996	0.184	0.833	0.832	0.031	1.865	2.050	0.427	0.197
134.110	28.500	0.187	0.834	0.834	0.033	2.143	2.124	0.465	0.180
134.110	29.000	0.190	0.835	0.834	0.033	1.920	2.025	0.267	0.121
134.110	29.500	0.194	0.837	0.836	0.034	2.215	2.086	0.357	0.136
134.110	30.000	0.197	0.836	0.835	0.035	2.145	1.994	0.346	0.142
134.110	30.500	0.200	0.834	0.833	0.036	2.326	2.313	0.379	0.124
134.110	31.000	0.203	0.835	0.834	0.036	2.708	2.273	0.420	0.120
134.108	31.500	0.207	0.831	0.831	0.038	3.103	2.717	0.491	0.103
134.110	32.000	0.210	0.829	0.827	0.045	3.623	3.019	0.430	0.069
134.112	32.500	0.213	0.818	0.816	0.047	4.316	3.555	0.642	0.074
134.112	33.000	0.217	0.808	0.806	0.055	4.968	3.965	1.076	0.096
134.112	33.500	0.220	0.788	0.786	0.057	6.136	4.919	0.634	0.037
134.110	34.000	0.223	0.768	0.765	0.066	7.490	5.428	-0.161	-0.007
134.110	34.500	0.226	0.724	0.720	0.081	10.500	6.502	0.296	0.008
134.110	35.000	0.230	0.663	0.655	0.103	12.706	7.297	-0.706	-0.013
134.110	35.500	0.233	0.583	0.570	0.121	14.694	8.901	9.429	0.127
134.110	36.000	0.236	0.488	0.469	0.134	16.592	10.406	11.262	0.115
134.110	36.500	0.240	0.360	0.336	0.129	16.794	12.065	22.992	0.200
134.110	37.000	0.243	0.261	0.237	0.109	14.317	13.184	28.001	0.261
134.112	37.500	0.246	0.193	0.168	0.094	12.693	13.231	17.622	0.185
134.112	38.002	0.249	0.166	0.152	0.067	12.720	12.786	8.538	0.092
134.112	38.500	0.253	0.188	0.186	0.030	13.909	10.391	-6.128	-0.075
134.112	39.000	0.256	0.253	0.252	0.020	16.296	9.802	-16.116	-0.178
134.112	39.502	0.259	0.345	0.345	0.011	16.558	8.593	-15.767	-0.195
134.112	40.000	0.262	0.438	0.438	-0.002	15.915	8.187	-13.279	-0.180
134.112	40.500	0.266	0.509	0.509	-0.014	15.267	7.360	-13.533	-0.212
134.112	41.000	0.269	0.577	0.576	-0.018	13.006	7.017	-6.700	-0.129
134.110	41.500	0.272	0.655	0.655	-0.031	12.336	6.264	-6.690	-0.153
134.112	42.000	0.276	0.728	0.726	-0.041	11.196	5.814	-9.887	-0.268
134.110	42.498	0.279	0.784	0.783	-0.051	7.842	4.749	-2.317	-0.110
134.110	43.000	0.282	0.807	0.805	-0.048	6.614	4.373	-2.477	-0.151
134.110	43.500	0.285	0.834	0.833	-0.049	4.425	3.669	-1.541	-0.167
134.110	44.000	0.289	0.844	0.842	-0.054	3.390	2.801	-0.810	-0.150
134.110	44.500	0.292	0.850	0.848	-0.049	2.638	2.341	0.198	0.056
134.110	45.000	0.295	0.853	0.852	-0.049	2.466	1.999	0.162	0.058
134.110	45.500	0.299	0.854	0.853	-0.048	2.268	1.774	0.138	0.061
134.110	46.000	0.302	0.856	0.855	-0.046	2.090	1.629	-0.063	-0.033
134.110	46.500	0.305	0.857	0.856	-0.043	2.315	1.556	0.128	0.063
134.110	47.000	0.308	0.857	0.856	-0.042	2.126	1.487	0.091	0.051
134.110	47.500	0.312	0.859	0.858	-0.041	2.032	1.429	0.186	0.113
134.110	48.000	0.315	0.860	0.860	-0.037	1.992	1.382	0.149	0.095
134.110	48.500	0.318	0.859	0.858	-0.035	2.178	1.359	0.100	0.059
134.110	49.000	0.322	0.862	0.861	-0.034	1.978	1.316	0.130	0.088
134.110	49.500	0.325	0.861	0.860	-0.032	2.256	1.325	0.105	0.062
134.110	50.000	0.328	0.862	0.862	-0.029	1.962	1.363	0.175	0.115
134.110	50.500	0.331	0.862	0.862	-0.029	1.979	1.293	0.155	0.107
134.110	51.000	0.335	0.863	0.863	-0.027	2.156	1.310	0.055	0.034
134.110	51.500	0.338	0.864	0.864	-0.023	1.933	1.298	0.135	0.095
134.110	52.000	0.341	0.863	0.862	-0.022	2.079	1.298	0.038	0.025
134.110	52.500	0.344	0.866	0.866	-0.021	1.951	1.331	0.211	0.143
134.110	53.002	0.348	0.864	0.864	-0.018	1.905	1.336	0.138	0.095
134.110	53.500	0.351	0.864	0.864	-0.018	1.834	1.272	0.109	0.082
134.110	54.000	0.354	0.865	0.865	-0.017	1.894	1.288	0.168	0.122
134.110	54.498	0.358	0.866	0.865	-0.015	1.950	1.286	0.126	0.089
134.110	54.998	0.361	0.866	0.866	-0.014	2.118	1.370	0.076	0.046

Survey Number 26									
Station 13									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
146.304	34.948	0.229	0.685	0.676	0.107	12.290	7.423	2.695	0.051
146.304	41.298	0.271	0.506	0.501	0.075	13.907	10.799	-7.595	-0.088
146.302	47.648	0.313	0.832	0.832	-0.005	2.527	2.527	-0.333	-0.090
146.302	53.998	0.354	0.846	0.846	-0.001	1.702	1.368	-0.007	-0.006
146.302	60.348	0.396	0.851	0.851	0.009	1.725	1.351	0.162	0.121
146.302	66.698	0.438	0.855	0.855	0.020	1.765	1.994	0.277	0.136
146.300	73.048	0.479	0.856	0.856	0.030	1.823	1.467	0.215	0.139
146.302	79.398	0.521	0.857	0.856	0.038	1.863	1.546	0.270	0.163
146.302	85.746	0.563	0.856	0.854	0.048	1.857	1.557	0.273	0.164
146.302	92.098	0.604	0.851	0.849	0.052	1.730	1.514	0.366	0.242
146.302	98.448	0.646	0.849	0.847	0.057	1.746	1.836	0.457	0.247
146.302	104.798	0.688	0.846	0.843	0.063	1.642	1.462	0.235	0.170
146.302	111.148	0.729	0.844	0.841	0.064	1.687	1.576	0.297	0.194
146.302	117.498	0.771	0.838	0.835	0.066	1.733	1.757	0.374	0.213
146.302	123.848	0.813	0.834	0.831	0.065	1.783	1.677	0.357	0.207
146.302	130.198	0.854	0.835	0.832	0.062	1.863	1.750	0.399	0.212
146.302	136.548	0.896	0.832	0.830	0.058	1.839	1.740	0.411	0.223
146.302	142.898	0.938	0.829	0.827	0.053	1.735	1.773	0.384	0.217
146.302	149.248	0.979	0.823	0.822	0.047	1.701	1.772	0.332	0.191
146.302	155.598	1.021	0.821	0.820	0.043	1.664	1.626	0.191	0.123
146.302	161.948	1.063	0.822	0.821	0.037	1.660	1.672	0.250	0.156
146.302	168.298	1.104	0.823	0.823	0.031	1.551	1.810	0.307	0.189
146.302	174.648	1.146	0.823	0.823	0.026	1.633	1.949	0.325	0.177
146.302	180.998	1.188	0.824	0.823	0.023	2.012	2.178	0.260	0.103
146.302	187.348	1.229	0.672	0.666	0.091	10.376	6.444	0.617	0.016
146.304	193.698	1.271	0.711	0.711	0.013	12.242	8.158	-11.352	-0.197
146.304	200.048	1.313	0.841	0.841	-0.008	1.763	1.472	0.071	0.048

Survey Number 27									
Station 13 Wake Survey #1									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
146.302	9.546	0.063	0.833	0.832	0.049	1.618	1.933	0.358	0.202
146.302	10.818	0.071	0.832	0.831	0.047	1.630	1.889	0.367	0.210
146.302	12.088	0.079	0.831	0.830	0.045	1.652	1.832	0.369	0.215
146.304	13.358	0.088	0.830	0.828	0.045	1.675	1.915	0.532	0.292
146.302	14.628	0.096	0.829	0.828	0.044	1.649	1.965	0.381	0.207
146.304	15.898	0.104	0.829	0.828	0.043	1.679	2.009	0.435	0.227
146.304	17.168	0.113	0.828	0.827	0.043	1.685	2.059	0.401	0.204
146.304	18.438	0.121	0.829	0.828	0.043	1.835	2.085	0.517	0.238
146.304	19.708	0.129	0.828	0.827	0.042	1.762	1.994	0.493	0.247
146.304	20.978	0.138	0.829	0.828	0.042	1.802	2.040	0.465	0.223
146.304	22.248	0.146	0.828	0.827	0.043	1.799	2.087	0.504	0.236
146.304	23.518	0.154	0.827	0.826	0.044	1.722	3.621	0.296	0.084
146.304	24.788	0.163	0.834	0.833	0.042	1.748	2.021	0.407	0.203
146.304	26.058	0.171	0.834	0.832	0.043	1.825	2.121	0.390	0.177
146.304	27.328	0.179	0.832	0.830	0.044	1.993	2.251	0.487	0.191
146.304	28.598	0.188	0.830	0.829	0.044	2.103	2.302	0.305	0.111
146.302	29.868	0.196	0.828	0.826	0.048	2.755	3.001	0.452	0.096
146.302	31.138	0.204	0.825	0.824	0.055	3.797	3.807	0.201	0.025
146.304	32.408	0.213	0.810	0.807	0.068	5.814	4.683	0.449	0.029
146.302	33.678	0.221	0.770	0.766	0.083	8.985	5.930	1.978	0.065
146.304	34.948	0.229	0.695	0.687	0.108	11.249	7.177	1.783	0.039
146.304	36.218	0.238	0.593	0.579	0.125	12.453	9.661	9.550	0.140
146.304	37.488	0.246	0.514	0.495	0.140	12.643	10.702	10.029	0.131
146.302	38.758	0.254	0.433	0.418	0.113	11.537	12.397	13.896	0.171
146.302	40.028	0.263	0.443	0.434	0.086	12.636	11.280	-1.832	-0.023
146.302	41.298	0.271	0.526	0.522	0.065	14.259	11.259	-10.690	-0.117
146.302	42.568	0.279	0.658	0.657	0.033	13.763	9.715	-16.044	-0.211
146.302	43.838	0.288	0.757	0.757	0.009	10.290	7.061	-6.399	-0.155
146.302	45.108	0.296	0.811	0.811	0.002	5.606	5.180	-2.553	-0.155
146.302	46.378	0.304	0.824	0.824	-0.003	3.957	3.525	-0.538	-0.068
146.302	47.648	0.313	0.829	0.829	-0.004	2.597	2.637	-0.014	-0.004
146.302	48.918	0.321	0.833	0.833	-0.005	2.239	2.009	-0.041	-0.016
146.302	50.188	0.329	0.836	0.836	-0.003	1.891	1.752	-0.069	-0.037
146.302	51.458	0.338	0.839	0.839	-0.003	1.866	1.565	0.007	0.004
146.302	52.728	0.346	0.841	0.841	-0.001	1.817	1.425	0.103	0.070
146.302	53.998	0.354	0.844	0.844	0.003	1.692	1.440	0.010	0.007
146.304	55.268	0.363	0.845	0.845	0.005	1.709	1.356	0.121	0.092
146.302	56.538	0.371	0.846	0.846	0.006	1.689	1.312	0.092	0.073
146.304	57.808	0.379	0.847	0.847	0.008	1.622	1.342	0.042	0.034
146.302	59.078	0.388	0.847	0.847	0.010	1.709	1.289	0.071	0.056
146.302	60.348	0.396	0.849	0.849	0.012	1.707	1.283	0.124	0.100

Survey Number 28									
Station 13 Wake Survey #2									
x(mm)	y(mm)	y/S	W/Vref	U/Vref	V/Vref	Tu	Tv	Re stress	Cuv
146.302	30.000	0.197	0.822	0.821	0.040	2.569	2.876	0.248	0.059
146.302	30.500	0.200	0.822	0.821	0.042	3.055	3.197	0.414	0.075
146.302	31.000	0.203	0.817	0.816	0.043	3.358	3.254	0.463	0.075
146.302	31.500	0.207	0.814	0.813	0.046	4.091	3.702	0.323	0.038
146.302	32.000	0.210	0.809	0.808	0.047	4.742	4.351	0.945	0.081
146.302	32.500	0.213	0.800	0.798	0.055	5.878	4.741	0.872	0.055
146.302	32.998	0.217	0.784	0.782	0.062	6.765	5.006	0.314	0.016
146.302	33.500	0.220	0.767	0.764	0.066	8.057	5.625	1.057	0.041
146.302	34.000	0.223	0.741	0.737	0.078	9.243	6.049	0.982	0.031
146.302	34.500	0.226	0.711	0.705	0.087	9.755	6.707	2.165	0.058
146.302	35.000	0.230	0.685	0.678	0.098	11.110	7.118	4.082	0.091
146.304	35.500	0.233	0.650	0.640	0.115	11.191	8.273	6.460	0.123
146.304	36.000	0.236	0.603	0.593	0.108	12.053	9.229	9.924	0.157
146.304	36.500	0.240	0.567	0.553	0.122	12.621	10.149	10.269	0.141
146.304	37.000	0.243	0.525	0.511	0.118	12.927	10.605	10.086	0.130
146.304	37.500	0.246	0.495	0.480	0.121	11.991	11.189	14.198	0.186
146.304	38.002	0.249	0.461	0.447	0.115	11.279	11.803	16.089	0.213
146.302	38.500	0.253	0.437	0.425	0.100	11.576	12.025	13.687	0.173
146.302	39.000	0.256	0.440	0.431	0.091	11.411	11.940	12.171	0.157
146.302	39.500	0.259	0.448	0.440	0.081	11.988	11.567	0.344	0.004
146.302	40.000	0.262	0.467	0.463	0.061	12.703	11.657	-7.780	-0.093
146.302	40.500	0.266	0.509	0.506	0.052	13.868	11.678	-12.659	-0.138
146.304	41.000	0.269	0.560	0.559	0.029	14.041	10.330	-16.260	-0.198
146.302	41.500	0.272	0.620	0.619	0.022	13.281	9.870	-10.125	-0.136
146.302	42.000	0.276	0.664	0.664	0.013	13.058	8.657	-12.139	-0.189
146.302	42.500	0.279	0.709	0.709	0.006	11.244	8.040	-9.651	-0.188
146.302	43.000	0.282	0.753	0.753	-0.001	9.501	7.026	-8.894	-0.235
146.302	43.500	0.285	0.776	0.776	-0.008	7.893	6.169	-5.039	-0.182
146.302	44.000	0.289	0.798	0.798	-0.006	6.478	5.032	-2.232	-0.121
146.302	44.500	0.292	0.810	0.810	-0.007	4.646	4.423	-2.200	-0.189
146.302	45.000	0.295	0.814	0.814	-0.006	3.827	3.419	-0.166	-0.022
146.302	45.500	0.299	0.823	0.823	-0.007	3.325	2.947	-0.084	-0.015
146.302	46.000	0.302	0.826	0.826	-0.007	2.836	2.855	-0.483	-0.105
146.302	46.500	0.305	0.826	0.826	-0.009	2.524	2.283	-0.309	-0.095
146.302	47.000	0.308	0.830	0.830	-0.009	2.339	1.988	0.035	0.013
146.302	47.500	0.312	0.827	0.827	-0.008	2.166	1.832	0.009	0.004
146.302	48.000	0.315	0.829	0.829	-0.007	2.218	1.702	-0.023	-0.011
146.302	48.500	0.318	0.831	0.831	-0.007	2.080	1.592	-0.014	-0.007
146.302	49.000	0.322	0.832	0.832	-0.008	1.908	1.509	-0.055	-0.033
146.302	49.500	0.325	0.831	0.831	-0.006	2.094	1.457	0.027	0.016
146.302	50.000	0.328	0.833	0.833	-0.006	1.927	1.375	0.057	0.038

APPENDIX D. REFERENCE VELOCITY CODE

FORTRAN CODE "CALIB1"

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C---------------------------------------------------------------------------------------------------------------C
C
      C
C   PROGRAM TO COMPUTE THE CALIBRATION CURVE FOR THE NPS LOW SPEED  C
C   CASCADE WIND TUNNEL.
      C
C
      C
C---------------------------------------------------------------------------------------------------------------C
C                                                                                                               C
C   A STRAIGHT LINE IS FITTED THROUGH THE REFERENCE CONDITIONS OF                                               C
C   THE TUNNEL AT DIFFERENT SPEEDS.                                                                             C
C                                                                                                               C
C   THE REFERENCE VELOCITY IS THEN OBTAINED, BY NEWTON'S METHOD,                                                C
C   DEPENDING ON THE TUNNEL PLENUM PRESSURE AND TEMPERATURE                                                     C
C                                                                                                               C
C---------------------------------------------------------------------------------------------------------------C
      PROGRAM CALIBRATE
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (NP=6)
      DIMENSION VA(NP),VT(NP),PA(NP),PP(NP),TP(NP)
      DIMENSION VTOT(NP),X(NP),ANUX(NP),PR(NP)
      DIMENSION PAR(100),PPR(100),TPR(100),PRR(100),ANUXR(100)
      DIMENSION VREF(100)
      CHARACTER*14 NAME(100)
C
      OPEN(UNIT=10,FILE='CALIB.DAT',STATUS='UNKNOWN')
      OPEN(UNIT=11,FILE='REFER.DAT',STATUS='UNKNOWN')
      OPEN(UNIT=12,FILE='CALIB.OUT',STATUS='UNKNOWN')
C
C   PRINT BANNER
C
      WRITE(*,500)
      WRITE(12,500)
  500 FORMAT(1X,78('C'),/1X,'C',76X,'C'/,
     #1X,'C',20X,'OUTPUT FROM PROGRAM CALIBRATE',27X,'C'/1X,'C',76X,'C'/
     #1X,78('C')//
     #5X,'LEAST SQUARES STRAIGHT LINE CURVE FIT IS USED'/
     #5X,'TO DETERMINE TUNNEL CHARACTERISTICS AT DIFFERENT SPEEDS'//
     #5X,'NEWTON S METHOD IS USED TO DETERMINE THE REFERENCE VELOCITY'/
     #5X,'FROM THE RECORDED AMBIENT PRESSURE AND TUNNEL PLENUM'/
     #5X,'PRESSURE AND TEMPERATURE'/)
C
C   INITIALIZE AIR, MERCURY AND WATER PROPERTIES
```

```
C
      RHOW=1000.D0
      RHOHG=13000.D0
      RHOA=1.2256D0
      CPA=1005.D0
      GAMMA=1.4D0
      GM1=GAMMA-1.D0
C
C    BEGIN DETERMINING TUNNEL CHARACTERISTICS
C
      WRITE(*,501)
      WRITE(12,501)
  501 FORMAT(//1X,'BEGIN DETERMINING TUNNEL CHARACTERISTICS',/
     #1X,'FROM THE FOLLOWING MEASURED VALUES',//
     #3X,'AXIAL VEL.       TANGENTIAL VEL.   AMBIENT PRESS.'
     #3X,'PLENUM PRESS.   PLENUM TEMP.'/
     #3X,'M PER SEC.          M PER SEC.      INCHES MERCURY'
     #3X,'INCHES WATER     DEG. C.'/)
C
C    READ IN DATA POINTS
C
C             VA = AXIAL VELOCITY          - MEASURED BY LDV (M/S)
C             VT = TANGENTIAL VELOCITY     - MEASURED BY LDV (M/S)
C             PA = AMBIENT PRESSURE          (INCHES MERCURY)
C             PP = PLENUM PRESSURE           (INCHES WATER)
C             TP = PLENUM STAGNATION TEMPERATURE         (DEG. C.)
C
      DO 1 I=1,NP
        READ(10,100)VA(I),VT(I),PA(I),PP(I),TP(I)
        WRITE(*,110)VA(I),VT(I),PA(I),PP(I),TP(I)
        WRITE(12,110)VA(I),VT(I),PA(I),PP(I),TP(I)
    1 CONTINUE
  100 FORMAT(1X,5F8.4)
  110 FORMAT(3X,F8.4,7X,F8.4,8X,F8.4,7X,F8.4,7X,F8.4)
C
C    CALC VTOT, X, ANUX AND PR
C
      WRITE(*,510)
      WRITE(12,510)
  510 FORMAT(/5X,'CALCULATED VALUES FOR THE TUNNEL CONFIGURATION',//
     #3X,'TOTAL VELOCITY',6X,'MACH NUMBER',9X,'MACH NUMBER FUNCT.',3X,
     #'PRESSURE RATIO'//)
C
      DO 2 I=1,NP
        VTOT(I)=DSQRT(VA(I)**2+VT(I)**2)
        X(I)=VTOT(I)/DSQRT(2.D0*CPA*(TP(I)+273.16D0))
        ANUX(I)=(GAMMA/GM1)*(X(I)**2)*(1.D0-(X(I)**2))**(1.D0/(GM1))
        PR(I)=1.D0-(RHOHG*PA(I))/(RHOW*PP(I)+RHOHG*PA(I))
        WRITE(*,101)VTOT(I),X(I),ANUX(I),PR(I)
        WRITE(12,101)VTOT(I),X(I),ANUX(I),PR(I)
    2 CONTINUE
```

```
 101 FORMAT(4D20.11)
C
C    CALL THE LEAST SQUARES SUBROUTINE TO FIT A STRAIGHT LINE THROUGH THE
C    DATA; X-AXIS = PR, Y-AXIS = ANUX (MACH NO. PARAMETER)
C
     WRITE(*,520)
     WRITE(12,520)
 520 FORMAT(/10X,'CALLING LEAST SQUARES SUBROUTINE',/1X,
    #'TO DETERMINE THE PRESSURE RATIO AS A FUNCTION OF MACH NO. PARAM'
    #//1X,'PRESSURE RATIO = A1 * ANUX + A0',//)
C
     CALL LEASTSQUARE(NP,ANUX,PR,A0,A1)
C
     WRITE(*,530)A1,A0
     WRITE(12,530)A1,A0
 530 FORMAT(/10X,'A1 = ',D20.11,'   A0 = ',D20.11/)
C
C     READ IN REFERENCE CONDITIONS
C
     WRITE(*,199)
     WRITE(12,199)
 199 FORMAT(/1X,'REFERENCE CONDITIONS FOR EACH RUN'/
    #1X,'AMBIENT PRESSURE   PLENUM PRESSURE   PLENUM TEMPERATURE',
    #3X,'RUN NAME'/
    #1X,' INCHES MERCURY    INCHES WATER     DEGREES CELSIUS'//)
C
C     THE NUMBER OF EXPERIMENTS
C
     READ(11,198)NE
 198 FORMAT(1X,I3)
C
C     THE REFERENCE CONDITIONS
C
     DO 99 I=1,NE
       READ(11,200)PAR(I),PPR(I),TPR(I),NAME(I)
       WRITE(*,201)PAR(I),PPR(I),TPR(I),NAME(I)
       WRITE(12,201)PAR(I),PPR(I),TPR(I),NAME(I)
  99 CONTINUE
 200 FORMAT(1X,3F8.4,A14)
 201 FORMAT(2(6X,F8.4),10X,F8.4,11X,A14)
C
C    CALCULATE THE PRESSURE RATIO
C
     DO 88 I=1,NE
       PRR(I)=1.D0-(RHOHG*PAR(I))/(RHOW*PPR(I)+RHOHG*PAR(I))
C
       ANUXR(I)=(-A0+PRR(I))/A1
C
       WRITE(*,550)I,PRR(I),ANUXR(I),NAME(I)
       WRITE(12,550)I,PRR(I),ANUXR(I),NAME(I)
 550 FORMAT(/1X,'I = ',I3,/
```

```
     #' PRESSURE RATIO = ',F10.5,' MACH NUMBER PARAMETER = ',E12.4,/
     #' RUN NAME = ',A14/)
C
C    NEWTON METHOD TO DETERMINE THE ROOTS OF THE EQUATION FOR ANUX
C
C    GUESS INITIAL VALUE OF VREF = VTOT(5)
C
      WRITE(*,560)
      WRITE(12,560)
  560 FORMAT(//10X,'BEGIN NEWTON ITERATION'/)
C
      KOUNT=1
      VREF(I)=VTOT(5)
      XR=VREF(I)/DSQRT(2.D0*CPA*(TPR(I)+273.16D0))
 1000 F=(GAMMA/GM1)*(XR**2)*(1.D0-(XR**2))**(1.D0/(GM1))-ANUXR(I)
      DFDX=(GAMMA/GM1)*2.D0*XR*((1.D0)-(XR**2)*(1.D0/(GM1)))*
     #     (1.D0-(XR**2)*(1.D0/GM1)*(1.D0/(1.D0-(XR**2))))
      TERM=F/DFDX
C
      WRITE(*,570)KOUNT,XR,TERM
      WRITE(12,570)KOUNT,XR,TERM
  570 FORMAT(1X,'ITERATION NUMBER ',I2,'  MACH NO. PARAM. = ',F8.6,
     #'    ERROR TERM = ',D12.4)
C
      XR=XR-(F/DFDX)
      KOUNT=KOUNT+1
      IF(DABS(TERM).LT.1.D-10)GO TO 999
      IF(KOUNT.LT.10.OR.DABS(TERM).GT.1.D-10)GO TO 1000
C
C    CALCULATE THE REFERENCE VELOCITY
C
  999 VREF(I)=XR*DSQRT(2.D0*CPA*(TPR(I)+273.16))
      WRITE(*,580)VREF(I)
      WRITE(12,580)VREF(I)
  580 FORMAT(/1X,'VREF = ',F20.11/)
   88 CONTINUE
C
C    PRINT FINAL RESULT
C
      WRITE(12,585)
  585 FORMAT(/1X,'EXPERIMENT NUMBER    REFERENCE VELOCITY    NAME'/)
      DO 777 I=1,NE
      WRITE(12,590)I,VREF(I),NAME(I)
  777 CONTINUE
  590 FORMAT(8X,I2,16X,F8.4,10X,A14)
      STOP
      END
C-----------------------------------------------------------------------C
C                                                                       C
C                                                                       C
C    A LEAST SQUARES CURVE FIT FOR A STRAIGHT LINE THROUGH NOISY        C
```

```
C   DATA                                                                    C
C                                                                           C
C   ALGORITHM TAKEN FROM: NUMERICAL METHODS, ROBERT W. HORNBECK              C
C                 PAGES 122 - 130, QUANTUM, 1975                             C
C                                                                           C
C---------------------------------------------------------------------------C
      SUBROUTINE LEASTSQUARE(N,X,FX,A0,A1)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION COEFF(2,2),RHS(2),X(N),FX(N)
C
C   SET UP COEFFICIENT MATRIX AND RIGHT HAND SIDE.
C
      COEFF(1,1)=N
      COEFF(1,2)=0.D0
      COEFF(2,2)=0.D0
C
      RHS(1)=0.D0
      RHS(2)=0.D0
C
      DO 2 I=1,N
        COEFF(1,2)=COEFF(1,2)+X(I)
        COEFF(2,2)=COEFF(2,2)+X(I)**2
        RHS(1)=RHS(1)+FX(I)
        RHS(2)=RHS(2)+X(I)*FX(I)
    2 CONTINUE
      COEFF(2,1)=COEFF(1,2)
C
C   PRINT MATRIX EQUATION
C
      WRITE(*,110)
      WRITE(12,110)
  110 FORMAT(/5X,'MATRIX EQUATION',/)
      DO 3 I=1,2
        WRITE(*,102)(COEFF(I,J),J=1,2),I-1,RHS(I)
        WRITE(12,102)(COEFF(I,J),J=1,2),I-1,RHS(I)
    3 CONTINUE
  102 FORMAT(5X,2(2X,D10.2),' A',I1,3X,D10.2)
C
C   GAUSS ELIMINATION
C
      TERM=COEFF(2,1)/COEFF(1,1)
C
      COEFF(2,2)=COEFF(2,2)-COEFF(1,2)*TERM
      RHS(2)=RHS(2)-RHS(1)*TERM
C
      A1=RHS(2)/COEFF(2,2)
      A0=(RHS(1)-COEFF(1,2)*A1)/COEFF(1,1)
C
      RETURN
      END
```

FORTRAN INPUT FILE “REFER.DAT”

```
28
29.9499 12.1000 21.1111  0502s13a____
29.9499 11.9000 21.1111  0502s13b____
29.9499 11.9000 21.1111  0502s13c____
29.9499 11.9000 21.1111  0502s12a____
29.9499 11.9000 21.1111  0502s12b____
29.8684 12.0000 20.0000  0506s11a____
29.8481 12.1000 20.5556  0506s10_____
29.8481 12.1000 20.5556  0506s9______
29.8481 12.1000 20.5556  0506s8______
29.8481 11.9000 21.6667  0506s7a_____
30.0517 12.0000 21.1111  0509s6a_____
30.0313 12.1000 20.5556  0509s5______
29.8888 12.0000 21.1111  0509s4______
29.8888 11.9500 20.5556  0507s3a_____
29.8888 11.9000 20.0000  0507s2a_____
29.9702 12.0000 21.1111  0401s1a_____
29.9295 11.9000 21.1111  0520s6b_____
29.9295 11.8000 22.2222  0520s11b____
29.9295 11.9500 22.2222  0520s11c____
29.9091 12.2000 22.2222  0520bp8_____
29.9499 11.9500 20.0000  0526s2b_____
29.9499 12.0000 20.5556  0526s3b_____
29.9295 11.9500 20.5556  0603bs5_____
29.9091 12.0000 25.5556  0708bs9_____
29.9295 11.9000 23.3333  0404s1b_____
29.8684 12.0000 22.2222  0901bs7_____
29.8481 11.8500 24.4444  0901bs7b____
29.8481 11.8000 25.0000  0901s7b_____
```

FORTRAN OUTPUT FILE "CALIB.OUT"

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                                                          C
C            OUTPUT FROM PROGRAM CALIBRATE                 C
C                                                          C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```

LEAST SQUARES STRAIGHT LINE CURVE FIT IS USED
TO DETERMINE TUNNEL CHARACTERISTICS AT DIFFERENT SPEEDS

NEWTON S METHOD IS USED TO DETERMINE THE REFERENCE VELOCITY
FROM THE RECORDED AMBIENT PRESSURE AND TUNNEL PLENUM
PRESSURE AND TEMPERATURE

BEGIN DETERMINING TUNNEL CHARACTERISTICS
FROM THE FOLLOWING MEASURED VALUES

AXIAL VEL. M PER SEC.	TANGENTIAL VEL. M PER SEC.	AMBIENT PRESS. INCHES MERCURY	PLENUM PRESS. INCHES WATER	PLENUM TEMP. DEG. C.
33.4750	24.5991	29.9499	3.6000	20.5556
42.7350	31.4532	29.9499	5.8000	21.6667
50.4851	37.3610	29.9499	8.1000	22.7778
56.1076	41.5132	29.9295	10.1000	23.3333
60.7966	45.0193	29.9295	11.9000	23.3333
65.9383	48.5611	29.9295	14.0000	23.8889

CALCULATED VALUES FOR THE TUNNEL CONFIGURATION

TOTAL VALOCITY	MACH NUMBER	MACH NUMBER FUNCT.	PRESSURE RATIO
0.41541441306E+02	0.54065475267E-01	0.10156165233E-01	0.91615012341E-02
0.53062076997E+02	0.68929132229E-01	0.16432468008E-01	0.14678018680E-01
0.62805968212E+02	0.81433418389E-01	0.22827031824E-01	0.20379988663E-01
0.69795476587E+02	0.90411111093E-01	0.28028521818E-01	0.25301646987E-01
0.75650273919E+02	0.97995252042E-01	0.32809629573E-01	0.29677031599E-01
0.81890413603E+02	0.10597930366E+00	0.38216120664E-01	0.34732257708E-01

CALLING LEAST SQUARES SUBROUTINE
TO DETERMINE THE PRESSURE RATIO AS A FUNCTION OF MACH NO. PARAM

PRESSURE RATIO = A1 * ANUX + A0

MATRIX EQUATION

0.60E+01 0.15E+00 A0 0.13E+00
0.15E+00 0.42E-02 A1 0.38E-02

A1 = 0.91276427032E+00 A0 = -0.26460149149E-03

REFERENCE CONDITIONS FOR EACH RUN

AMBIENT PRESSURE INCHES MERCURY	PLENUM PRESSURE INCHES WATER	PLENUM TEMPERATURE DEGREES CELSIUS	RUN NAME
29.9499	12.1000	21.1111	0502s13a____
29.9499	11.9000	21.1111	0502s13b____
29.9499	11.9000	21.1111	0502s13c____
29.9499	11.9000	21.1111	0502s12a____
29.9499	11.9000	21.1111	0502s12b____
29.8684	12.0000	20.0000	0506s11_____
29.8481	12.1000	20.5556	0506s10_____
29.8481	12.1000	20.5556	0506s9______
29.8481	12.1000	20.5556	0506s8______
29.8481	11.9000	21.6667	0506s7______
30.0517	12.0000	21.1111	0509s6a_____
30.0313	12.1000	20.5556	0509s5______
29.8888	12.0000	21.1111	0509s4______
29.8888	11.9500	20.5556	0507s3a_____
29.8888	11.9000	20.0000	0507s2a_____
29.9702	12.0000	21.1111	0401s1a_____
29.9295	11.9000	21.1111	0520s6b_____
29.9295	11.8000	22.2222	0520s11a____
29.9295	11.9500	22.2222	0520s11b____
29.9091	12.2000	22.2222	0520bp8_____
29.9499	11.9500	20.0000	0526s2b_____
29.9499	12.0000	20.5556	0526s3b_____
29.9295	11.9500	20.5556	0603bs5_____
29.9091	12.0000	25.5556	0708bs9_____
29.9295	11.9000	23.3333	0404s1b_____
29.8684	12.0000	22.2222	0901bs7_____
29.8481	11.8500	24.4444	0901bs7b____
29.8481	11.8000	25.0000	0901s7b_____

EXPERIMENT NUMBER	REFERENCE VELOCITY	NAME
1	75.9548	0502s13a____
2	75.3334	0502s13b____
3	75.3334	0502s13c____
4	75.3334	0502s12a____
5	75.3334	0502s12b____
6	75.6033	0506s11a____
7	76.0105	0506s10_____
8	76.0105	0506s9______

9	76.0105	0506s8_____
10	75.5311	0506s7a_____
11	75.5184	0509s6a_____
12	75.7816	0509s5_____
13	75.7209	0509s4_____
14	75.4939	0507s3a_____
15	75.2668	0507s2a_____
16	75.6195	0401s1a_____
17	75.3587	0520s6b_____
18	75.1875	0520s11b____
19	75.6570	0520s11c____
20	76.4587	0520bp8_____
21	75.3466	0526s2b_____
22	75.5733	0526s3b_____
23	75.4433	0603bs5_____
24	76.2651	0708bs9_____
25	75.6427	0404s1b_____
26	75.8893	0901bs7_____
27	75.7288	0901bs7b____
28	75.6417	0901s7b_____

APPENDIX E. GRAPE AND RVCQ3D INPUT AND PCP CODE

"GRAPE" INPUT

```
&GRID1
 JMAX=340,KMAX=49,NTETYP=3,NAIRF=5,JAIRF=343,NIBDST=7,
 DSI=0.0002,JTEBOT=80,JTETOP=261,XLE=0.0,NOBSHP=7,XTE=1.0,
 ALAMF=0.0,ALAMR=0.0,XLEFT=-.5,XRIGHT=3.,
 RCORN=.10,NOUT=4,NORDA=5,3,MAXITA=0,300,
 &END
 &GRID2
 AAAI=.3,BBBI=.3,DSOBI=0.01,ROTANG=-16.3,
 XTFRAC=1.5,PITCH=1.1976,DSRA=.4920,DSLE=.0008,DSTE=.001,
 NLE=48,NTE=36,WAKEP=1.,OMEGR=1.0,OMEGS=1.0,OMEGP=1.0,OMEGQ=1.0,
 &END
 &GRID3 AIRFX=
  127.0533,  127.0025,  126.9898,  126.9467,  126.8984,  126.8400,
  126.7714,  126.6927,  126.5961,  126.4768,  126.3752,  126.2990,
  126.2228,  126.1466,  125.9942,  125.7656,  125.3084,  125.0798,
  124.9274,  124.6988,  124.5464,  124.3940,  124.2416,  124.0892,
  124.0130,  123.9368,  123.8606,  123.7844,  123.7082,  123.6320,
  123.5558,  123.4796,  123.3906,  123.0276,  122.6646,  122.3016,
  121.9386,  121.5757,  121.2127,  120.6435,  120.0744,  119.5052,
  118.9361,  118.3669,  117.7978,  117.0168,  116.2359,  115.4549,
  114.6740,  113.8930,  113.1121,  112.1089,  111.1057,  110.1025,
  109.0993,  108.0961,  107.0929,  105.8614,  104.6300,  103.3985,
  102.1671,  100.9356,   99.7041,   98.4585,   97.2128,   95.9671,
   94.7214,   93.4757,   92.2300,   90.9738,   89.7175,   88.4612,
   87.2049,   85.9486,   84.6923,   83.4351,   82.1778,   80.9205,
   79.6632,   78.4059,   77.1486,   75.8955,   74.6423,   73.3891,
   72.1360,   70.8828,   69.6296,   68.3811,   67.1327,   65.8842,
   64.6357,   63.3872,   62.1387,   60.8997,   59.6607,   58.4217,
   57.1827,   55.9437,   54.7047,   53.4707,   52.2368,   51.0028,
   49.7689,   48.5350,   47.3010,   46.0678,   44.8346,   43.6014,
   42.3682,   41.1350,   39.9019,   38.6769,   37.4520,   36.2270,
   35.0021,   33.7771,   32.5522,   31.3293,   30.1064,   28.8835,
   27.6606,   26.4377,   25.2148,   24.0073,   22.7998,   21.5923,
   20.3848,   19.1774,   17.9699,   16.9731,   15.9764,   14.9797,
   13.9829,   12.9862,   11.9894,   11.2059,   10.4225,    9.6390,
    8.8555,    8.0720,    7.2885,    6.7058,    6.1230,    5.5402,
    4.9574,    4.3747,    3.7919,    3.4079,    3.0239,    2.6399,
    2.2560,    1.8720,    1.4880,    1.4199,    1.3437,    1.2675,
    1.1913,    1.1151,    1.0389,    0.9627,    0.8865,    0.8103,
    0.7341,    0.6579,    0.5817,    0.5055,    0.4293,    0.3531,
    0.2921,    0.1956,    0.1270,    0.0762,    0.0381,    0.0102,
   -0.0051,   -0.0127,   -0.0152,   -0.0152,   -0.0127,   -0.0051,
    0.0076,    0.0279,    0.0559,    0.0889,    0.1270,    0.1702,
    0.2210,    0.2794,    0.3454,    0.4221,    0.7466,    1.0712,
    1.3957,    1.7202,    2.0448,    2.3693,    2.8953,    3.4214,
```

```
 3.9474,   4.4734,   4.9995,   5.5255,   6.2765,   7.0276,
 7.7786,   8.5297,   9.2807,   10.0317,  11.0113,  11.9910,
 12.9706,  13.9503,  14.9299,  15.9096,  17.1240,  18.3385,
 19.5530,  20.7675,  21.9820,  23.1965,  24.4399,  25.6833,
 26.9267,  28.1700,  29.4134,  30.6568,  31.9316,  33.2064,
 34.4812,  35.7560,  37.0308,  38.3056,  39.6119,  40.9182,
 42.2245,  43.5307,  44.8370,  46.1433,  47.4763,  48.8092,
 50.1422,  51.4752,  52.8081,  54.1411,  55.4884,  56.8358,
 58.1831,  59.5304,  60.8777,  62.2250,  63.5654,  64.9057,
 66.2461,  67.5864,  68.9268,  70.2671,  71.5759,  72.8847,
 74.1935,  75.5023,  76.8111,  78.1199,  79.3932,  80.6665,
 81.9398,  83.2130,  84.4863,  85.7596,  87.0079,  88.2561,
 89.5044,  90.7527,  92.0010,  93.2493,  94.4762,  95.7031,
 96.9301,  98.1570,  99.3840,  100.6109, 101.8351, 103.0593,
104.2835, 105.5077, 106.7319, 107.9562, 108.9738, 109.9914,
111.0091, 112.0267, 113.0444, 114.0620, 114.8767, 115.6915,
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126.6114, 126.6673, 126.7231, 126.7714, 126.8197, 126.8628,
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127.0711, 127.0864, 127.1118, 127.1245, 127.1118, 127.0787,
127.0533,
AIRFY=
 1.0617,   0.9855,   0.9093,   0.8331,   0.7569,   0.6807,
 0.6045,   0.5283,   0.4521,   0.3759,   0.3200,   0.2819,
 0.2489,   0.2210,   0.1702,   0.1194,   0.0838,   0.0914,
 0.1067,   0.1448,   0.1803,   0.2210,   0.2667,   0.3200,
 0.3505,   0.3810,   0.4140,   0.4470,   0.4826,   0.5232,
 0.5613,   0.6045,   0.6577,   0.8979,   1.1299,   1.3544,
 1.5718,   1.7825,   1.9871,   2.2968,   2.5944,   2.8820,
 3.1614,   3.4345,   3.7031,   4.0671,   4.4257,   4.7782,
 5.1240,   5.4623,   5.7926,   6.2042,   6.6019,   6.9862,
 7.3577,   7.7168,   8.0641,   8.4753,   8.8712,   9.2538,
 9.6248,   9.9861,   10.3395,  10.6901,  11.0331,  11.3669,
 11.6900,  12.0012,  12.2988,  12.5843,  12.8558,  13.1147,
 13.3621,  13.5993,  13.8275,  14.0479,  14.2594,  14.4611,
 14.6519,  14.8307,  14.9963,  15.1474,  15.2840,  15.4055,
 15.5113,  15.6010,  15.6742,  15.7302,  15.7704,  15.7957,
 15.8072,  15.8060,  15.7932,  15.7698,  15.7350,  15.6877,
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 13.6245,  13.3564,  13.0778,  12.7917,  12.4966,  12.1926,
 11.8797,  11.5580,  11.2275,  10.8891,  10.5426,  10.1886,
 9.8278,   9.4608,   9.0881,   8.7149,   8.3365,   7.9522,
 7.5617,   7.1646,   6.7604,   6.4211,   6.0769,   5.7279,
 5.3741,   5.0158,   4.6531,   4.3647,   4.0722,   3.7742,
 3.4694,   3.1562,   2.8332,   2.5860,   2.3330,   2.0747,
 1.8115,   1.5438,   1.2721,   1.0910,   0.9086,   0.7247,
```

```
 0.5397,   0.3536,   0.1666,   0.1321,   0.0991,   0.0711,
 0.0457,   0.0279,   0.0127,   0.0000,  -0.0025,  -0.0051,
-0.0025,   0.0025,   0.0178,   0.0381,   0.0660,   0.0991,
 0.1346,   0.2108,   0.2870,   0.3632,   0.4394,   0.5156,
 0.5918,   0.6680,   0.7391,   0.7442,   0.8204,   0.8966,
 0.9728,   1.0490,   1.1252,   1.2014,   1.2776,   1.3538,
 1.4300,   1.5062,   1.5824,   1.6596,   1.9804,   2.2930,
 2.5977,   2.8950,   3.1850,   3.4682,   3.9135,   4.3429,
 4.7579,   5.1599,   5.5503,   5.9304,   6.4574,   6.9667,
 7.4587,   7.9337,   8.3922,   8.8345,   9.3880,   9.9173,
10.4250,  10.9137,  11.3861,  11.8448,  12.3975,  12.9336,
13.4531,  13.9565,  14.4440,  14.9158,  15.3830,  15.8350,
16.2726,  16.6967,  17.1081,  17.5077,  17.9059,  18.2919,
18.6653,  19.0255,  19.3718,  19.7037,  20.0282,  20.3364,
20.6277,  20.9017,  21.1577,  21.3953,  21.6180,  21.8200,
22.0006,  22.1587,  22.2936,  22.4043,  22.4910,  22.5527,
22.5896,  22.6023,  22.5911,  22.5566,  22.4993,  22.4186,
22.3138,  22.1843,  22.0292,  21.8481,  21.6457,  21.4189,
21.1691,  20.8976,  20.6055,  20.2942,  19.9741,  19.6386,
19.2894,  18.9281,  18.5564,  18.1759,  17.7956,  17.4077,
17.0114,  16.6061,  16.1909,  15.7652,  15.3362,  14.8987,
14.4552,  14.0081,  13.5599,  13.1131,  12.6704,  12.2301,
11.7911,  11.3519,  10.9113,  10.4680,  10.0967,   9.7226,
 9.3460,   8.9668,   8.5851,   8.2011,   7.8922,   7.5826,
 7.2734,   6.9654,   6.6594,   6.3565,   6.1300,   5.9042,
 5.6775,   5.4485,   5.2154,   4.9770,   4.8173,   4.6541,
 4.4871,   4.3159,   4.1398,   3.9587,   3.8811,   3.8049,
 3.7287,   3.6525,   3.5763,   3.5001,   3.4239,   3.3477,
 3.2715,   3.1953,   3.1191,   3.0429,   2.9667,   2.8905,
 2.8143,   2.7381,   2.6619,   2.5857,   2.5095,   2.4333,
 2.3571,   2.2809,   2.2047,   2.1285,   2.0523,   1.9761,
 1.8999,   1.8237,   1.6713,   1.4808,   1.2903,   1.1379,
 1.0617,
&END
```

"RVCQ3D" INPUT

```
'GELDER CONTROLLED DIFFUSION BLADE'
 &NL1 M=340,N=49,MTL=80,MIL=143 &end

 &NL2 NSTG=4,IVDT=1,IRS=1,EPI=.30,EPJ=.40,CFL=4.0 AVISC2=0., EPS=0.4,
    AVISC4=1. &END

 &NL3 IBCIN=1,IBCEX=1,ITMAX=5000,IRESTI=0,IRESTO=1,IRES=1,ICRNT=10000,
    IXRM=0 &END

 &NL4 AMLE=0.22,ALLE=36.5,BETE=0,PRAT=0.9767,P0IN=1.0,T0IN=1.0,G=1.40,
    &END

 &NL5 ILT=4,JEDGE=30,RENR=1.0e6,PRNR=.70,TW=0.0,VISPWR=.666666,
    CMUTM=14.0,ITUR=2 &END

 &NL6 OMEGA=0.0,NBLADE=1,NMN=2 &end

 &NL7 TINTENS=0.02 &end
-.3000 3.000
1.0000 1.000
1.0000 .9709
```

"PCP" CODE

```
C--------------------------------------------------------------C
C    PROGRAM TO READ THE OUTPUT FROM RVCQ3D.F AND GRAPE.F    C
C    AND GENERATE A DATA FILE FOR A P/P0 VS CHORD PLOT     C
C    AROUND THE AIRFOIL. AUG.22, 1991                  C
C--------------------------------------------------------------C
c     IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION Q(400,400,4),X(400,400),Y(400,400)
      DIMENSION U(400,400),V(400,400),P(400,400)
C
C    CALCULATE THE CRITICAL VELOCITY
      cepe=1.00
      rgas=1.0
      pi=1.0
      ti=1.0
      PRAT=0.685
      rhoi=pi/(rgas*ti)
      ceve=cepe-rgas
      g=1.40
      gp=g+1
      cstar=sqrt(2*g*pi/(gp*rhoi))
C
      ISTART=80
      IFINIT=261
C
      READ(7,*)NI,NJ
      print *,ni,nj
      READ(7,*)((X(I,J),I=1,NI),J=1,NJ),
     &         ((Y(I,J),I=1,NI),J=1,NJ)
      READ(7,*)MTL,MIL
C
      READ(3,*)NI,NJ
      READ(3,*)FSMACH,ALF,RE,TIME
      READ(3,*)(((Q(I,J,K),I=1,NI),J=1,NJ),K=1,4)
C
      GAMMA=1.4
C
      DO 1234 I=1,NI
      DO 4321 J=1,NJ
      U(I,J)=Q(I,J,2)/Q(I,J,1)
      V(I,J)=Q(I,J,3)/Q(I,J,1)
      P(I,J)=(GAMMA-1)*(Q(I,J,4)-.5*Q(I,J,1)*(U(I,J)**2+V(I,J)**2))
     &      *RHOI*CSTAR**2
 4321 CONTINUE
 1234 CONTINUE
C
C    DETERMINE THE XMIN AND XMAX GRID POINT POSITION
      XMIN=0.0
      XMAX=0.0
```

```
      DO 2 I=ISTART,IFINIT
       IF(X(I,1).LE.XMIN)THEN
       IMIN=I
        PRINT *,IMIN
       XMIN=X(I,1)
       END IF
       IF(X(I,1).GE.XMAX)THEN
       IMAX=I
c       PRINT *,IMAX
       XMAX=X(I,1)
       END IF
    2 CONTINUE
C
C     FREE STREAM STATIC PRESSURE USES THE XMIN GRID POINT
      P0=P(IMIN,NJ)+.5*Q(IMIN,NJ,1)*(U(IMIN,NJ)**2+V(IMIN,NJ)**2)
     &            *RHOI*CSTAR**2
C
      i=imin
      j=nj
      t0=1/rgas*((g-1)*q(i,j,4)/q(i,j,1)-(g-1)**2/(2*g)*
     &   (q(i,j,2)**2+q(i,j,3)**2)/q(i,j,1)**2)
      t0=t0*cstar**2
c     print *,p0,t0,p(imin,nj),q(imin,nj,1),u(imin,nj),v(imin,nj)
C
C     CALCULATE THE MASS FLOW RATE FROM THE INPUT DATA
C     NORMALIZED WITH THE INLET AREA
      dmass=pi/(rgas*ti)*(1/prat)**(-1/g)*sqrt(g*(g-1)*rgas*ti/2*
     &     (1-1/(1/prat)**((g-1)/g)))
c     print *,'cal. inlet mass flow rate =',dmass,'* area'
C
      dmasse=q(imin,nj,1)*RHOI*u(imin,nj)
c     print *,'comp. inlet mass flow rate / area =',dmasse
C
C     PRINT OUT DOWN STREAM CONDITIONS
      p1=p(1,1)+.5*q(1,1,1)*(u(1,1)**2+v(1,1)**2)*RHOI*CSTAR**2
      t1=1/rgas*((g-1)*q(1,1,4)/q(1,1,1)-(g-1)**2/(2*g)*
     &   (q(1,1,2)**2+q(1,1,3)**2)/q(1,1,1)**2)
      t1=t1*CSTAR**2
c     print *,'downstream condition'
c     print *,p1,t1,p(1,1),q(1,1,1),u(1,1),v(1,1)
C
C     calculate the mass flow rate at exit
      smass=0.0
      ra=0.0
      ba=0.0
      do 21 j=1,nj-1
      smass=smass+(q(1,j,1)+q(1,j+1,1))*(u(1,j)+u(1,J+1))*
     &     RHOI*CSTAR*(abs(y(1,j+1)-y(1,j)))*0.25
      ra=ra+(q(1,j,1)+q(1,j+1,1))*(abs(y(1,j+1)-y(1,j)))*0.5*
     &     RHOI
      ba=ba+abs(y(1,j+1)-y(1,j))
```

```
   21  continue
       do 22 j=1,nj-1
       smass=smass+(q(ni,j,1)+q(ni,j+1,1))*(u(ni,j)+u(ni,J+1))*
     &      RHOI*CSTAR*(abs(y(ni,j+1)-y(ni,j)))*0.25
       ra=ra+(q(n1,j,1)+q(ni,j+1,1))*(abs(y(ni,j+1)-y(ni,j)))*0.5
     &      *RHOI
       ba=ba+abs(y(ni,j+1)-y(ni,j))
   22  continue
C
C      average velocity
       va=smass/ra
       dr=ra/ba
c      print *,'vel. downsteam,vd =',va
c      print *,'ave. density,dr =',dr
C
C      CALCULATE THE INPUT INLET VELOCITY
C      NORMALIZED BY CSTAR
       c0=sqrt(g*rgas*ti)
       vin=sqrt(g*(g-1)*rgas*ti/2*(1-(1/prat)**((1-g)/g)))/c0
c      print *,'input inlet velocity / c0 =',vin
C
C      CALCULATE THE CORRECTED DOWNSTREAM VELOCITY
       do 23 j=nj,1,-1
       vac=u(ni,j)*vin/va
       alpha=atan(abs(v(ni,j)/u(ni,j)))
       vtc=vac*tan(alpha)
       vc=sqrt(vac**2+vtc**2)
       yy=abs(y(ni,nj)-y(1,nj))
c      write(24,*)abs(y(ni,j)-y(ni,nj))/yy,vc
   23  continue
C
       do 25 j=2,nj
       vac=u(1,j)*vin/va
       alpha=atan(abs(v(1,j)/u(1,j)))
       vtc=vac*tan(alpha)
       vc=sqrt(vac**2+vtc**2)
c      write(24,*)abs(y(1,j)-y(ni,nj))/yy,vc
   25  continue
C
C
       CHORD=ABS(X(IMAX,1)-X(IMIN,1))
C
       DO 1 I=ISTART,IFINIT
        DIST=ABS(X(I,1)-X(IMIN,1))
        XS=DIST/CHORD
        CP=1.0+(-P0+P(I,1))/(.5*Q(IMIN,NJ,1)*(U(IMIN,NJ)**2
     &                 +V(IMIN,NJ)**2)*RHOI*CSTAR**2)
        vvcr=sqrt(u(i,1)**2+v(i,1)**2)
C       THE SURFACE POINT P(I,1) ALWAYS EQUAL 0 ?
        PT=P(I,1)/P0
c       WRITE(63,*)XS,VVCR
```

```
c      WRITE(64,*)XS,PT
      WRITE(65,*)XS,CP
    1 CONTINUE
C
      STOP
      END
```

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